# USE OF ADVANCED SATELLITE SYSTEMS FOR GLOBAL AIR TRAFFIC CONTROL AND NAVIGATION

## HEARING

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS

OF THE

## COMMITTEE ON SCIENCE AND TECHNOLOGY HOUSE OF REPRESENTATIVES

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# USE OF ADVANCED SATELLITE SYSTEMS FOR GLOBAL AIR TRAFFIC CONTROL AND NAVIGATION

WEDNESDAY, SEPTEMBER 24, 1986

HOUSE OF REPRESENTATIVES, COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON TRANSPORTATION, AVIATION, AND MATERIALS,

*Washington, DC.*

The subcommittee met, pursuant to call, at 9:50 a.m., in room 2325, Rayburn House Office Building, Hon. George E. Brown, Jr. (chairman of the subcommittee) presiding.

Mr. LEWIS [acting chairman]. I call the Subcommittee on Transportation, Aviation, and Materials to order. It's going to be a few minutes before Mr. Glickman gets here, and a little more time will be required before Mr. Brown gets here, so we're speaking for the record primarily, and we'll start the meeting at this point in time.

Today's hearing is on advanced satellite systems—the use of advanced satellite systems for global air traffic control and navigation. I have an opening statement that I would like to read for the record.

Aviation has a very broad constituency, and satisfying the needs of this various group always presents a challenge. It is clear that a great deal of thought and planning has to go into any modernization scheme; that takes time.

The current air transportation system modernization scheme is still years away from completion, and already it is time to begin looking beyond the NAS plan for new improvements—new ways to increase capacity—and improve the safety of the air transportation system.

The communication, navigation, and surveillance system is certainly the heart of any air transportation system, and satellite technology promises to significantly enhance the safety and efficiency of today's system.

However, in the implementation of any new system, problems invariably arise, especially with respect to its transition. It is particularly difficult for general aviation to respond quickly to every new requirement in avionics replacement. Therefore, it is important that every effort be made to minimize the burden to the users.

I am pleased to see that the FAA is giving serious thought to these issues. I am also encouraged by the cooperation of the users groups and look forward to hearing from some of these today.

Our first panel will be Mr. David D. Thomas, chairman of Special Committee 155 of the Radio Technical Commission on Aero-

nautics; William Hardaker, vice chairman; James Kramer, manager, Advanced Technical Programs, General Electric; Gilbert F. Quinby of G.F. Quinby Associates; James E. Gorham, director, James E. Gorham Associates; and Ulf R.C. Gustafsson, staff engineer, avionics, United Airlines.

Gentlemen. Mr. Thomas, why don't you lead off.

**STATEMENTS OF DAVID D. THOMAS, CHAIRMAN, SPECIAL COMMITTEE 155, RADIO TECHNICAL COMMISSION FOR AERONAUTICS; JAMES KRAMER, MANAGER, ADVANCED TECHNICAL PROGRAMS, GENERAL ELECTRIC; GILBERT F. QUINBY, G.F. QUINBY ASSOCIATES; JAMES E. GORHAM, DIRECTOR, JAMES E. GORHAM ASSOCIATES; AND ULF R.C. GUSTAFSSON, STAFF ENGINEER, AVIONICS, UNITED AIRLINES, INC.**

Mr. THOMAS. Mr. Chairman, I'm David D. Thomas. I'm the chairman of the Special Committee 155 of the Radio Technical Commission for Aeronautics—RTCA. This committee was established late in 1983 for the purpose of determining user requirements for future communications, navigation, and surveillance systems including space technology applications.

I'd like to introduce the panel. Captain Hardaker, whom you mentioned, is in London today at the Royal Institute of Navigation talking on this very same subject and the findings of 155. On my extreme right is Dr. James Kramer, chairman of the Technology Working Group. Dr. Kramer's task was to examine new technologies to see what their applications might be to the user requirements in future systems.

To my immediate right is Gilbert F. Quinby who chaired the Operations Working Group. Mr. Quinby had the task of finding out the various and sometimes conflicting views of all the users of the airspace and welding them together into a common view, which I think he did very successfully.

On my immediate left is Mr. James E. Gorham who chaired the Transition/Economics Working Group. We looked at costs, cost-benefits, the methods of transition, and the economics, and it was one of the very active and very critical portions of our work; and on my extreme left is Mr. Gustafsson of United Airlines. He was very active, as were a number of the other user representatives, in helping us come up with some conclusions on the work of the panel.

Before we go into what we did, I might take just a moment to look at RTCA. It's an organization that's slightly over 50 years old. It's supported by both Government and industry. It has about 125 members, and RTCA has no authority within itself; its total activity is coordination and its strength lies in the validity of the views that it finally comes up with and the actions of its members who supported it.

RTCA works through special committees. We happen to be 155 since its origination, and perhaps one of the most significant committees was back in 1938, SC-31—I'm sorry, 1948. SC-31 on air traffic control won the Collier Trophy in 1950, and it was presented by President Harry Truman, for the establishment of a guide plan for the development and implementation of a system of air navigation and air traffic control to facilitate safe and unlimited aircraft

operations under all weather conditions. The very excellent system that we enjoy today, nearly 40 years later, is based on the forward thinking of those who hammered out the SC-31 recommendations.

We have now about the same opportunities that they had 40 years ago and newer technologies coming on to the scene that we need to look at. The coming into being of the U.S. Department of Defense Global Positioning System will lead the way for highly accurate navigation services everywhere on the globe. Satellite systems are satisfying communications needs for a number of users. Advances in digital signal processing are impressive. Inertial navigation systems have set new standards for accuracy and reliability. Tremendous advances have been made in data handling and computational capabilities. Thus, we have about the same opportunities to embrace new technologies as we did back then.

The potential of all these new technologies for communications, navigation, and surveillance systems is almost limitless, and an endless number of combinations and permutations could be considered. However, the usefulness of any of them will be minimal unless and until there is universal agreement as to the role that each will play in the future systems and a well thought out transition plan is developed.

For this reason, during the SC-155 process, international implications were always considered as the future system must have global application to be of value. In fact, much of the value of the SC-155 product is to assist the United States in developing its position in a similar ongoing study by the International Civil Aviation Organization.

We looked at 2010 as a focal point, snapshot year, in considering future systems, and we thought that transition from current systems from future systems might still be in progress, as a quarter of a century is a relatively short time to make global changes in communications, navigation, and surveillance systems.

The fundamental change foreseen by SC-155 is the use of compatible ground-based and satellite-based systems to provide communications, navigation, and surveillance services in all the airspace usable by aircraft. We recognize that the development and deployment of global space networks goes far beyond the scope of any plan confined to a single national area or region of the world and will require international cooperation, planning, and support. It would be very imprudent and short sighted to curtail any current improvement programs while laboring through the slow process of developing and proving acceptable satellite systems and then resolving international funding and management issues.

Existing systems worldwide are land based, and the entire aviation industry is geared to these systems. It is particularly important that efforts to improve airspace systems in the United States or other countries not be delayed. SC-155 looked beyond the current national airspace system plan and outlined transition into a possible but not yet available system in the post-NASP period.

The most complete, yet succinct overview of the work of SC-155 is contained in the conclusions and recommendations section of the final report which follows. Mr. Chairman, I can brief these down, but we spent about 2½ years in making them this concise, and if it

meets with your pleasure, I'd prefer to read them to be sure we don't miss any.

Mr. GLICKMAN [acting chairman]. Sure. Go ahead.

Mr. THOMAS. This is taken verbatim from our report.

The greatest deficiencies in the current airspace systems are: (1) Lack of sufficient airport/heliport facilities in major city areas; (2) lack of low altitude CNS coverage in most areas of the world; (3) lack of instrument approach capability to many paved and lighted airports and other aircraft operating areas; (4) lack of surveillance information from much of the space over oceans and unpopulated areas; (5) lack of air traffic control system capabilities that make efficient use of the airspace and landing areas; and (6) inadequate air/ground communications lacking in both capacity and coverage.

The current U.S. national airspace plan, when completed, will satisfy some of these deficiencies, but there will still be some unmet requirements in the United States. These are: (1) In areas below line-of-sight coverage from the ground-based VHF and higher frequency aids; and (2) at landing areas which do not have terminal landing aids; (3) in any airspace where flight is restricted due to limited air traffic control capabilities. There will be these and other unmet requirements worldwide, especially in oceanic and other unpopulated or sparsely populated regions of the world.

The most effective way to correct all CNS coverage deficiencies appears to be through the use of satellites, although adequate navigation service may continue to be provided to meet some requirements in some areas by (a) lower frequency aids such as Loran-C, Omega, lower/medium frequency beacons; and (b) self-contained devices such as inertial navigation systems. However, global communications coverage from land-based aids would be difficult and not completely reliable. Global surveillance independent of airborne navigation information is unlikely by means other than satellites.

The absolute limiting factor for aviation growth will be the number of airports and the effective use of their capacity. Better CNS services can assist saturated airports become more productive by providing a basis for greater precision in making approaches and separating traffic.

Improvement in the en route phase of flight, including climb and descent, will depend primarily on the existence of an airspace management system that will permit each flight to operate on its most favorable trajectory without intervention except as necessary to avoid collision with another aircraft.

Ideally, the airspace management system should permit the operator of each flight to select and operate on routes and altitudes of his choosing and deviate only when and to the extent necessary to avoid another aircraft, without either aircraft being subject to violent, evasive maneuvers. Future system benefits rely almost totally on the extent to which this ideal airspace management concept can be achieved.

From information available now, it seems unlikely that satellite-based navigation systems will be useful as precision landing aids to very low weather minima without some ground-based assistance. However, it may be expected that instrument approaches—that is, weather conditions worse than visual, meteorological conditions where one could see the ground, down to lower limits not yet deter-

mined—can be made to any location where the landing site location and approach path obstructions are known in three dimensions.

Rotocraft operations to any site under low visibility conditions—for example, rescue at a highway accident scene—may require additional airborne aides, such as infrared devices or terrain mapping radar, to fill the gap between satellite navigational coordinates and map accuracies, including terrain altitudes, at sites not previously visited. Otherwise, the full potential of rescue and similar services may not be realized.

Ground-based CNS services will continue to be used at selected terminal areas. The airborne equipment, other than for precision landing navigation, should operate with both satellite-based and ground-based CNS equipment.

Satellite-based CNS services may use satellites in various orbits depending on the coverage desired. Full global coverage will require some inclined-orbit satellites. Geostationary satellite signal coverage is generally limited to the Earth surface between the latitudes of 65 degrees north to 65 degrees south, although successful communications tests with airborne aircraft as far as 75 degrees north have been conducted with geostationary satellites. However, geostationary satellites alone do not provide adequate position determination in equatorial regions. Thus, unless augmented, they are not suitable for either navigation or independent surveillance in those areas.

Global navigation services under the management of a single agency may be acceptable. It is unlikely that communications and surveillance services will be managed on other than a national or regional basis even though facilities and raw data may be provided by commercial organizations.

To facilitate CNS services worldwide, the transmission characteristics, data format, and modulation of airborne communication and surveillance systems must be uniform and standardized. To minimize the amount of onboard equipment, it should be possible to accommodate both the satellite-relayed and the terrestrial-based services in one airborne device.

Any form of navigation meeting stated accuracy, reliability, and other requirements should be acceptable worldwide as the source for automatic dependent surveillance data.

The key to improved efficiency lies in producing an airspace management system that we have described. A necessary basis for such a system is continuous surveillance and instantly available air-ground communications with all aircraft in the airspace involved. This presumes that all aircraft in that airspace will be equipped with communications and surveillance cooperating devices compatible with the airspace management system.

Navigation may be from different sources. An improved airspace management system that makes more efficient use of available airspace provides benefits for all aviation users by minimizing capacity constraints with an improved level of safety.

Communications technology will make voice and data transmissions possible everywhere and in sufficient capacity for any currently perceived need.

Preservation of adequate spectrum capacity will continue to be a primary concern for the national and international community. As increasing utilization of airspace imposes higher communication and surveillance burdens on airspace management, satellite relay systems will supplement very high frequency and high frequency technologies.

A growing proportion of communications traffic will be as data which will continue to take advantage of technologies of new data rate and frequency reuse. Aeronautical radio frequency allocation are limited resources, and their users accept the responsibility for their efficient use.

Navigation systems which are based on satellite systems will make position determination available to relatively inexpensive receivers. Such systems will have sufficient accuracy for all aviation applications except precision approach and landing in very low visibilities. More precise navigation aids such as those in use or planned for the terminal areas will continue to be required.

Next, we will use the words, "automatic dependent surveillance"—that's a word of art almost, which means the airplane reports automatically its position as it is derived from the cockpit back to the traffic control agency—will be available through the combined use of aircraft position determination systems and a complete coverage communications capability.

Cooperative independent surveillance—which means, in effect, the airplane carries some device such as the present radar transponder beacon—can be obtained by the use of satellite systems.

Fully independent en route surveillance—satellite-based primary radar—does not appear to be feasible for civil aviation use early in the next century. Emerging high technology may provide the basis for surveillance completely independent of aircraft equipment and systems but on a schedule that is impossible to predict at this time.

Mr. Chairman, those were our conclusions, and then we came to the following recommendations. We recommended that:

*(A)* The U.S. FAA adopt as a planning goal the provisions of communications, navigation, and surveillance services throughout the airspace under its jurisdiction or control from the surface to at least 70,000 mean sea level with provision for expansion to include higher altitudes as needed for flights of civil aircraft that may routinely use higher altitudes.

*(B)* The method of providing air traffic control in the en route airspace, both in the United States and internationally, be changed from reliance on fixed tracks and routes with limited altitude flexibility to a system of air traffic management that will permit each flight to operate on its desired trajectory without intervention except as necessary to avoid collision with another aircraft or to avoid weather hazards.

It is noted that the FAA plans to introduce this concept in the United States at higher altitudes, and the FAA is urged to proceed as rapidly as facilities and personnel resources permit. It is further recommended that the U.S. Government promote the adoption of this goal by other nations and international bodies.

*(C)* U.S. and international research, development, and standardization efforts, including cost/benefit analyses, be directed toward: (1) Aeronautical communications systems that will: (a) Work with

both satellite and terrestrial stations, both with voice and digital data; (b) serve as the communications link for dependent surveillance systems; (2) dependent surveillance systems that automatically report air determined navigation information; (3) satelliite navigation systems intended for use as a sole means navigation service; (4) a uniform cooperative independent surveillance system for worldwide aviation, including use of satellite and terrestrial capabilities, as appropriate.

*(D)* Selection from among the candidate systems emerging from the research and development process be based on benefits and costs apparent to both the user and the provider.

*(E)* The use of automatic dependent surveillance in oceanic and other areas not covered by ground-based radar be introduced as rapidly as the concept is proven safe, reliable, and economic in each such area.

*(F)* Action within radio frequency spectrum regulatory agencies, both domestic and international, insure that adequate spectrum allocations are provided to meet the requirements of the future aviation CNS systems.

*(G)* Action be taken for airport and heliport system expansion and improvement so that the benefits of improved CNS services may be realized.

*(H)* Determination of institutional arrangements for the provision and management of CNS systems take the best advantage of their capabilities in a manner mutually acceptable to the users and the sovereign nations involved.

Mr. Chairman, this work has just been completed. The document has not been printed in final form, but some word processor copies, I believe, have been made available for the use of your committee for the complete report.

That completes my prepared statement. I believe other members of the panel may have prepared statements, if you so desire.

[The prepared statement of Mr. Thomas follows:]

Statement of

David D. Thomas, Chairman

Special Committee 155 of
the Radio Technical Commission for Aeronautics

before the

Subcommittee on Transportation,
Aviation and Materials

United States House of Representatives
Committee on Science and Technology

September 24, 1986

1

Mr. Chairman, I am David D. Thomas, Chairman of Special Committee 155 (SC-155) of the Radio Technical Commission for Aeronautics (RTCA) which was established late in 1983 for the purpose of determining user requirements for future communications, navigation, and surveillance (CNS) systems, including space technology applications.

Many others who played significant roles in the development of the SC-155 report. First, is the vice chairman, Captain William T. Hardaker, a distinguished Naval Aviator, who has also served in executive capacities in the Federal Aviation Administration and the Air Transport Association of America. Captain Hardaker could not be here today, as he is in England presenting a paper on the activities of RTCA SC-155 to a Royal Institute of Navigation Symposium. However, we do have the Chairman of the three working groups of SC-155 appearing with me to supplement this testimony and respond to questions.

Next is Gilbert F. Quinby, Chairman of the Operations Working Group, who is now a consultant after spending many years' in the avionics manufacturing field. Mr. Quinby is also a pilot of many years experience. His function in SC-155 was to guide the process by which users with diverse, and sometimes conflicting, operational requirements come to consensus on future requirements.

Next is James J. Kramer, Chairman of the Technology Working Group. Mr. Kramer has broad government and industry experience as a scientist dealing with advanced technologies. He was a former Associate Administrator of NASA for Aeronautics and Space Technology and is now Manager, Advanced Technology Programs for General Electric Company. His task was to guide SC-155 in exploring rapidly changing technologies that might have applications in future systems.

Next is Mr. James E. Gorham, Chairman of the Transition/Economics Working Group. Mr. Gorham has extensive experience in aviation economics in both government and industry. He is presently Chairman of the Transportation Research Board, Economics and Research. He served with the former Civil Aeronautics Board and now serves as a consultant doing aviation economic analyses and forecasts. His task was to guide the forecast, economic analysis, cost-benefit studies, and transition planning.

Last is Mr. Ulf Gustafsson, Staff Engineer, Avionics Engineering, United Airlines. Mr. Gustaffsson, as an engineer, pilot and a user representative played a leading role in SC-155 activities, particularly in the areas of requirements and cost/benefit considerations.

Obviously, there were many others who contributed greatly to the work of SC-155, but the panel before you is representative of the knowledge, experience and skills that went into this work.

SC-155 worked under the direction of a steering committee, composed of airspace users chaired by Mr. John H. Winant, President of the National Business Aircraft Association. The Steering Committee device is rarely used in RTCA, but was used in this case to emphasize the importance of keeping the effort of this Special Committee focused on user requirements. Mr. Winant is unable to be here today as he had a prior committments on the West Coast.

Before describing the findings of SC-155, it may be helpful to describe briefly the Radio Technical Commission for Aeronautics. The RTCA is a non-profit organization, formed in 1935, for the purposes of coordination of effort, exchange of views, and producing consensus solutions to common problems in all phases of aviation involving the application of electronics and telecommunications.

The general membership of RTCA is currently composed of over 125 government and industry organizations. It is supported by U. S. government departments and agencies and aviation industry members, but it does not represent or speak for any of them. The role of RTCA is one of coordination without authority or implementation powers. The strength of RTCA recommendations is derived from the combined force and authority of its constituents.

RTCA works through Special Committees on problems which come to it principally from its members. In the case of SC-155, the Federal Aviation Administration was the originating member. Participants in Special Committees are volunteers who receive no reimbursement from RTCA. There were 318 participants in SC-155.

The work of Special Committees of RTCA is the basis for most minimum performance standards used by manufacturers and governments for virtually all aviation communications, navigation and surveillance systems used today.

One notable RTCA Special Committee whose findings are well known even today was SC-31 on "Air Traffic Control" which completed its work in February 1948. That work was the basis for President Harry S. Truman presenting the Collier Trophy to RTCA in 1950 "for the establishment of a guide plan for the development and implementation of a system of air navigation and air traffic control to facilitate safe and unlimited aircraft operations under all weather conditions." The excellent system we have today - nearly 40 years later - is based on the forward thinking of those who hammered out SC-31 recommendations four decades ago.

The pre-World War II air navigation and air traffic control system was based on low frequency navigation aids, and high frequency air-ground communications. World War II accelerated new technologies, including radar for independent surveillance and VHF communications, and the world was made ready for global air transportation. SC-31 forged the best possible system out of then available technologies.

Today we are reporting on the work of another RTCA Special Committee, SC-155, which had as its task the development of statements of operational and technical requirements of the users of civil aviation systems for communications, navigation and surveillance (CNS) for at least the next quarter century. The need for this work arises form the rapid and accelerating development of technology that will be available for future systems. The most impressive new technologies involve the growing use of satellites for data transmissions.

The coming into being of the U. S. Department of Defense Global Positioning System will lead the way for highly accurate navigation services everywhere on the globe. Satellite systems are now satisfying communications needs for a number of users. Advances in digital signal processing are impressive. Inertial navigation systems have set new standards for accuracy and reliability. Tremendous advances have been made in data handling and computational capabilities. Thus, we have today some of the same kinds of opportunities to embrace technologies as did our predecessors who guided the work of SC-31.

The potential of new technology for communication, navigation and surveillance systems is almost limitless and an almost endless number of combinations and permutations could be considered. However, the usefulness of any of them will be minimal unless and until there is universal agreement as to the role each will play in future systems and a well thought-out transition plan is developed. For this reason, during the SC-155 process, international implications were always considered, as the future system must have global application to be of value. In fact, much of the value of the SC-155 product is to assist the United States in developing its position in a similar ongoing study by the International Civil Aviation Organization.

The SC-155 Committee also recognized that functions other than communications, navigation, and surveillance will influence system capacities and efficiencies. Among the most important of these are airport access and capacity and air traffic management efficiency. Although neither of these functions were addressed in detail by SC-155, the effects of future CNS systems on these systems were considered to be supportive of improvements, particularly in the area of air traffic management.

SC-155 selected the year 2010 as a focal point in considering future systems. It was assumed that currently planned system improvements would be made, and that development, testing and implementation of new systems could be completed by that target year. It was assumed also that transition from current systems to future systems could still be in progress as a quarter of a century is a relatively short time in which to make global changes in communication, navigation and surveillance systems.

The fundamental change foreseen by SC-155 is the use of compatible ground-based and satellite-based systems to provide communications, navigation ans surveillance services in all airspace usable by aircraft. We recognize thac the development and deployment of global space networks goes far beyond the scope of any plan confined to a single national area or region of the world, and will require international cooperation, planning and support. It would be very imprudent and short-sighted to curtail any current improvement programs while laboring through the slow process of developing and proving acceptable satellite systems, and then resolving international funding and management issues.

Existing systems worldwide are land based and the entire aviation industry is geared to these systems. It is particularly important that current systems improvement programs now being undertaken in the United States, or any other country, not be delayed waiting for newer technology. Sc-155 looked beyond the

Existing systems worldwide are land based and the entire aviation industry is geared to these systems. It is particularly important that efforts to improve airspace systems now in the United States, or other countries, not be delayed. SC-155 looked beyond the current National Airspace System Plan (NASP) and outlined transition into possible, but not yet available, systems in the post-NASP period.

The most complete, yet succinct overview of the work of SC-155 is contained in the "Conclusions and Recommendations" section of the Final Report, which follows:

## 10.0 CONCLUSIONS AND RECOMMENDATIONS

### 10.1 Conclusions

a. The greatest deficiencies in the current airspace system are (1) lack of sufficient airport/heliport facilities in major city areas; (2) lack of low altitude CNS coverage in most areas of the world; (3) lack of instrument approach capability to many paved and lighted airports and other aircraft operating areas; (4) lack of surveillance information from much of the space over oceans and unpopulated areas; (5) lack of ATC system capabilities that make efficient use of the airspace and landing areas; and (6) inadequate air/ground communications lacking in both capacity and coverage.

b. The current U.S. NASP, when completed, will satisfy some of these deficiencies, but there will still be unmet requirements in the United States:

(1) in areas below line-of-sight coverage from ground-based VHF and higher frequency aids.
(2) at landing areas which do not have terminal landing aids.
(3) in any airspace where flight is restricted due to limited ATC capabilities.

c. There will be these and other unmet requirements worldwide, especially in oceanic and other unpopulated or sparsely populated regions of the world.

d. The most effective way to correct all CNS coverage deficiencies appears to be through the use of satellites, although adequate navigation service may continue to be provided to meet some requirements in some areas by a) lower frequency aids, such as Loran-C, Omega, L/MF beacons, and b) self-contained devices, such as inertial navigation systems. However, global communications coverage from ground-based aids would be difficult and not completely reliable. Global surveillance independent of airborne navigation information is unlikely by means other than satellites.

e. The absolute limiting factor for aviation growth will be the number of airports and the effective use of their capacity. Better CNS services can assist saturated airports to become more productive by providing a basis for greater precision in making approaches and separating traffic.

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f. Improvement in the en route phase of flight including climb and descent will depend primarily on the existence of an airspace management system that will permit each flight to operate on its most favorable trajectory without intervention except as necessary to avoid collision with another aircraft. Ideally, the airspace management system should permit the operator of each flight to select and operate on routes and altitudes of his choosing and deviate only when and to the extent necessary to avoid another aircraft, without either aircraft being subjected to violent evasive maneuvers. Future system benefits rely almost totally on the extent to which this ideal airspace management concept can be achieved.

g. From information available now, it seems unlikely that satellite-based navigation systems will be useful as precision landing aids to very low weather minima without some ground-based assistance. However, it is expected that instrument approaches (weather conditions worse than VMC down to lower limits not yet determined) can be made to any location where the landing site location and approach path obstructions are known in three dimensions.

Rotorcraft operations to any site under low visibility conditions (for example, rescue at a highway accident scene) may require additional airborne aids, such as infra-red devices or terrain mapping radar, to fill the gap between satellite navigational coordinates and map accuracies (including terrain altitudes) at sites not previously visited. Otherwise the full potential of rescue and similar services may not be realized.

h. Ground-based CNS services will continue to be used at selected terminal areas. The airborne equipment, other than for precision landing navigation, should operate with both satellite-based and ground-based CNS equipment.

i. Satellite-based CNS services may use satellites in various orbits depending on the coverage desired. Full global coverage will require some inclined-orbit satellites. Geostationary satellite signal coverage is generally limited to the earth surface area between the latitudes of 65 degrees North to 65 degrees South, although successful communications tests with airborne aircraft as far as 75 degrees North have been conducted with geostationary satellites. However, geostationary satellites alone do not provide adequate position determination in equatorial regions. Thus, unless augmented, they are not suitable for either navigation or independent surveillance in those areas.

j. Global navigation services under the management of a single agency may be acceptable. It is unlikely that communications and surveillance services will be managed on other than a national or

regional basis even though facilities and raw data may be provided by commercial organizations.

k. To facilitate CNS services worldwide, the transmission characteristics, data format and modulation of airborne communication and surveillance systems must be uniform and standardized. To minimize the amount of on-board equipment, it should be possible to accommodate both the satellite-relayed and terrestrial-based services in one airborne device.

l. Any form of navigation meeting stated accuracy, reliability and other requirements should be acceptable worldwide as the source for automatic dependent surveillance data.

m. The key to improved efficiency lies in producing an airspace management system as described in paragraph f. above. A necessary basis for such a system is continuous surveillance and instantly available air-ground communications with all aircraft in the airspace involved. This presumes that all aircraft in that airspace will be equipped with communications and surveillance cooperating devices compatible with the airspace management system. Navigation may be from different sources. An improved airspace management system that makes more efficient use of available airspace provides benefits for all aviation users by minimizing capacity constraints with an improved level of safety.

n. Communications technology will make voice and data transmissions possible everywhere and in sufficient capacity for any currently perceived need.

o. Preservation of adequate spectrum capacity will continue to be a primary concern for the national and international community. As increasing utilization of airspace imposes higher communication and surveillance burdens on airspace management, satellite relay systems will supplement VHF and HF technologies. A growing proportion of communication traffic will be as data which will continue to take advantage of new technologies of data rate and frequency re-use. Aeronautical radio frequency allocations are limited resources, and their users accept the responsibility for their efficient use.

p. Navigation systems which are based on satellite systems will make position determination available to relatively inexpensive receivers. Such systems will have sufficient accuracy for all aviation applications except precision approach and landing in very low visibilities. More precise navigation aids such as those in use or planned for the terminal areas will continue to be required.

q. Automatic dependent surveillance will be available through the combined use of aircraft position determination systems and a complete coverage communications capability.

r. Cooperative independent surveillance can be obtained by the use of satellite systems.

s. Fully independent en route surveillance (satellite-based primary radar) does not appear to be feasible for civil aviation use early in the next century. Emerging high technology systems may provide the basis for surveillance completely independent of aircraft equipment and systems but on a schedule that is impossible to predict at this time.

10.2 Recommendations

It is recommended that:

a. The U.S. FAA adopt as a planning goal, the provision of communications, navigation and surveillance services throughout the airspace under its jurisdiction or control from the surface to at least 70,000 feet MSL with provision for expansion to include higher altitudes as needed for flights of civil aircraft that may routinely use higher altitudes.

b. The method of providing air traffic control in the en route airspace, both in the U. S. and internationally, be changed from reliance on fixed tracks and routes with limited altitude flexibility to a system of air traffic management that will permit each flight to operate on its desired trajectory without intervention except as necessary to avoid collision with another aircraft or to avoid weather hazards. It is noted that the FAA plans to introduce this concept in the U.S. at higher altitudes and the FAA is urged to proceed as rapidly as facilities and personnel resources permit. It is further recommended that the U.S. government promote the adoption of this goal by other nations and international bodies.

c. U.S. and international research, development, and standardization efforts, including cost/benefit analyses, be directed towards:

(1) Aeronautical communications systems that will:

(a) work with both satellite and terrestrial stations, both with voice and digital data,

(b) serve as the communications link for dependent surveillance systems.

(2) Dependent surveillance systems that automatically report air determined navigation information.

(3) Satellite navigation system(s) intended for use as a sole means navigation service.

(4) A uniform cooperative independent surveillance system for worldwide aviation including use of satellite and terrestrial capabilities as appropriate.

d. Selection from among candidate systems emerging from the research and development process be based on benefits and costs apparent to both user and provider.

e. The use of automatic dependent surveillance in oceanic and other areas not covered by ground-based radar be introduced as rapidly as the concept is proven safe, reliable, and economic in each such area.

f. Action within radio frequency spectrum regulatory agencies both domestic and international insure that adequate spectrum allocations are provided to meet the requirements of the future aviation CNS systems.

g. Action be taken for airport and heliport system expansion and improvement so that the benefits of improved CNS services may be realized.

h. Determination of institutional arrangements for the provision and management of CNS systems take the best advantage of their capabilities in a manner mutually acceptable to the users and the sovereign nations involved.

The work of SC-155 has just been completed with the approval of the RTCA Executive Committee as recently as September 19, 1986. Therefore, our report has not been published in final form, but word-processor format copies are available for use of your committee pending final publication.

Mr. Chairman, that completes my prepared statement. Thank you.

Mr. GLICKMAN. Well, I didn't know whether you wanted us to get to questions now or whether anybody else on the panel would prefer to make any sort of formal statement. It's up to you in that regard. I just think from the standpoint of questions, it would probably be useful if we were able to—maybe we can get some of what you are going to talk about pulled out in the form of questions, but that's up to you.

Mr. THOMAS. As you wish, Mr. Chairman.

I believe that the other two statements will amplify and maybe go into a little more detail. So we can do it either way.

Mr. GLICKMAN. Why don't we go ahead with questions. All your statements will appear in the record, and then when we get to these questions, it can give more time for give-and-take.

First of all, I want to compliment you on the report. This subcommittee has been involved in this question of satellite navigation for some time, and it was highlighted by the 007 problems with Korean Airlines where we were looking for ways to better deal with navigation over oceans in uncontrolled areas that obviously had something to do with that particular scenario.

But let me ask you first of all if I understand what you are saying in this report. Are you saying that you apparently believe that the NAS plan—the airspace plan that's on the books now should be leapfrogged in favor of immediate pursuit of a satellite system?

I guess what I'm saying is, it seems to me from reading what you are talking about that you are suggesting restructuring an airspace plan to accommodate satellite technology. If that's the case, it means major modifications to the NAS plan, because there is a lot of institutional inertia in the way our Government operates, and if we're going to do that, I want you to tell us that that's what you think needs to be done.

Mr. THOMAS. Mr. Chairman, I think several of us would probably like to comment on that.

First, we assume that the NAS plan would be in place as the building block from which we would progress. As a matter of fact, much of the NAS plan has to be there as a bedrock on which we can go ahead and develop the rest of this.

I think Mr. Quinby, who had the Operations Working Group, who dealt with the users on what their requirements, has a statement, and then I think Mr. Gustafsson from United Airlines would like to make a statement on that.

Mr. GLICKMAN. Sure. Go ahead, Mr. Quinby.

Mr. QUINBY. Thank you.

Mr. GLICKMAN. Why don't you speak into the mike, so we can hear you.

Mr. QUINBY. Is that OK?

Mr. GLICKMAN. Sure.

Mr. QUINBY. I won't bother you with my whole statement, it's in the record, but I would like to read a paragraph which speaks directly to your question, Mr. Chairman.

One of the most difficult chapters to write in the final report was the chapter on transition. It seems that the national airspace system is in a continual state of transition fueled by the emergence of new aircraft capabilities and new technologies. It was gratifying

to watch FAA participate in the work of the committee and incorporate into its own planning as worthy ideas gained committee consensus.

As a result, it may be said that transition toward the national airspace system of 25 years in the future is already under way. We would expect the work of SC-125 to support and supplement FAA's present evolving national airspace system plan, certainly not substitute for it.

[The prepared statement of Mr. Quinby follows:]

RTCA Paper No. 445-86/RE-547

Statement of

Gilbert F. Quinby

Special Committee 155 of
the Radio Technical Commission for Aeronautics

before the

Subcommittee on Transportation,
Aviation Materials

United States House of Representatives
Committee on Science and Technology

September 24, 1986

Mr. Chairman, my name is Gilbert F. Quinby. I have enjoyed 44 years of active participation in the evolution of radio applications in aviation. I have over 4000 hours of experience as a pilot of general aviation aircraft. It was my privilege to chair the Operations Working Group of RTCA Special Committee 155.

SC-155's Chairman David D. Thomas has offered a broad overview of the charter, objectives, conclusions and recommendations of SC-155. I would like to amplify a few points in his testimony with particular regard to the task, composition and methods of SC-155's Operations Working Group.

In its charter from FAA, our committee was directed to establish airspace user needs for future communication, navigation and surveillance services first, and then select from available or realistically expectable technologies the best means to satisfy those needs. The Operations Working Group was able to start with an honest "clean sheet of paper" and present the rest of the committee with an interim report of user needs unbiased by concerns of cost or technical feasibility. It took 11 months of intense committee work by a remarkable group of qualified spokesmen for all types of airspace users. Representatives of major airlines, staffed by the Air Transport Association, negotiated patiently with other users of the airspace while protecting their unique needs. General Aviation was represented by competent staff personnel from the Aircraft Owners and Pilots Association. Business aircraft operators were represented by the National Business Aircraft Association. Smaller scheduled air carriers were represented by the Regional Airline Associations, and the special needs of the rotorcraft operators were kept in our minds by the Helicopter Association International. Finally, a competent officer from the U.S. Air Force was a faithful participant to remind us that our military is an important user of airspace. Canadian and European participation was constructive, and non-user resource people from industry and government contributed to the organization and preparation of our interim report. Considering the wide divergence of operating philosophies in the working group, the degree of consensus in their report is noteworthy. Some disagreements survived despite repeated attempts at negotiation. Agreements and disagreements are carefully documented in Appendix D of the final report of the committee.

As our statement of needs or operating requirements was subjected to technical realities by the Technology Working Group and to fiscal facts of life by the Transition and Economics Working Group, we were concerned that our needs might not survive without significant change. All three working groups spent 1985 developing a very rough first draft of a final report. Early in 1986 the Operations Working Group met to compare the refined statements of user needs in the draft final report with those in our interim report over a year old. Although the sheet of paper was no longer clean, the basic statements of user needs had survived remarkably well.

One of the most difficult chapters to write in the final report was the chapter on transition. It seems that the National Airspace System is in a continual state of transition fueled by the emergence of new aircraft capabilities and new technologies. It was gratifying to watch FAA incorporate the work of the committee into its own planning as worthy ideas gained

committee consensus. As a result, it may be said that transition toward the National Airspace System of 25 years in the future is already under way. We would expect the work of SC-155 to support and supplement FAA's present National Airspace System Plan; certainly not substitute for it. The present NAS plan is well underway and sorely needed to fill the inordinate amount of years needed to research, engineer, develop and prove new system elements. Some NAS plan elements, such as the Microwave Landing System, have yet to demonstrate their benefits in full operational use in spite of many years of research and development. Similarly, some elements of the system for the years beyond 2010 may not be reduced to practice until after the turn of the century.

That completes my prepared statement, Mr. Chairman. Thank you for this opportunity.

Mr. GLICKMAN. So you're not then in favor of junking the NAS plan.

Mr. QUINBY. Definitely not, Mr. Chairman.

Mr. GLICKMAN. All right. How about leapfrogging the NAS plan?

Mr. QUINBY. I would prefer to use the term "evolving the NAS plan."

Mr. GLICKMAN. Then what substantive changes do you think need to be made in the NAS plan to accommodate satellite technology?

Mr. QUINBY. Well, satellite technology has not—was not incorporated in the original NAS plan. Some considered that an oversight. Perhaps the consideration at that time was premature. Incorporation in the NAS plan of today is certainly not premature, and we will hear more about that from Mr. Gustafsson, I'm sure.

By the same token, the microwave landing system as an example of an evolving system element, this was first considered over 20 years ago as a concept, and it has yet to be reduced to operational practice to get good data. I think it's important that it be reduced as quickly as possible and we start collecting information so as to make full use of the microwave landing system. It is incorporated in the SC-155 plan as ongoing through the next 25 years. Now that's an example of the kind of good and bad points of the NAS plan that need to be considered and corrected and evolved.

Mr. GLICKMAN. Mr. Gustafsson, did you have some comments on this particular question?

Mr. GUSTAFSSON. I had a prepared statement and definitely would support that the NAS plan is a very important transition instrument for getting into what we have been talking about in SC-155. It is a building block.

We have always looked at the NAS plan as being a fluid plan, and it can easily evolve into what we are talking about in SC-155. But you cannot junk it. There will be some ideas that may be redirected in the later end of the NAS plan but definitely not the way it is started.

The advanced automation system, for instance, is a very important building block to go into what we are talking about in SC-155.

[The prepared statement of Mr. Gustafsson follows:]

STATEMENT BY ULF R. C. GUSTAFSSON

STAFF ENGINEER - AVIONICS, UNITED AIRLINES

BEFORE THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY, SUB-COMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS - ON THE USE OF ADVANCED SATELLITE SYSTEMS FOR GLOBAL AIR TRAFFIC CONTROL AND NAVIGATION IN RELATION TO THE FINDINGS OF RTCA SPECIAL COMMITTEE 155.

SEPTEMBER 24, 1986.

Mr. Chairman and Members of the Sub-Committee:

I value this opportunity to appear before the sub-committee today to give one airline's view on the introduction of satellite technology in the global airspace system serving civil aviation. My comments, both technical and operational, will be directed specifically towards the area of greatest concern to United Airlines in the work of RTCA SC-155, namely that new technologies be allowed to reshape the airspace system to better accommodate air transportion.

United Airlines chose to participate in RTCA Special Committee 155 because it promised an opportunity for the airspace users to define what we each need 25 years from now. United believes in planning for the future, and we are continually trying to enhance safety and to improve our operations, our environment and our efficiency. I am proud of what was accomplished in SC-155 and I hope and expect that the report gets the wide circulation and the attention it deserves.

As United entered into the SC-155 work, it was clear to us that airspace users were going to be faced with the introduction of two untapped technologies, proven in other applications but new to aviation, namely satellite-based communications, navigation and surveillance facilities plus automation of the Air Traffic Control process. There were plans to make use of new technology but only to replace old tools, not to specifically improve the way the system functions.

A little story will illustrate what I mean. My old home town is by a river and, when I grew up, there was a ferry across. Then they decided to build a bridge instead and needed to determine how wide to make it. Since the bridge replaced the ferry, they simply counted the traffic on the ferry and concluded that all that was needed was one lane in each direction. Needless to day, when the bridge was finished, there were plans for a new suburb on the other side - limited by the capacity of the bridge.

We run the same risk in this case - of planners assuming that satellite communication will only replace High Frequency radios, that automatic position reports will just replace voice reports and that automation means having computers do just what the human controller used to do. But these new technologies have so much more to contribute in improving the airspace system by increasing the safety, the capacity, the flexibility and the efficiency.

We feel that new technology should never be accepted for its own sake; it must improve the old ways, either by cost savings or by improved capabilities.

A further reason for a major airline to participate in the planning for the future is to ensure that the global perspective is maintained. We cannot endorse the development of different systems, equipment and procedures for different parts of our route network.

An important fact to consider is that - as in the case of the bridge - we can only afford to do this once; we have to be right the first time.

So what do we expect from the future airspace system?

We feel strongly that the new technologies of satellites and automation should be applied to open up the airspace and allow efficient air transportation while increasing the safety level from what we see today.

In SC-155 we agreed on the term Airspace Management System to indicate that we saw a future where managing airspace, not controlling air traffic, was the first concern. The most important purpose of such an airspace management function is to assure separation between aircraft. This should be done by monitoring the traffic, rather than by controls and procedures as forced by the lack of sophistication in today's Air Traffic Control system.

The ATC system now is tied to outdated assumptions and limitations which result in separating aircraft from usable airspace and imposing artificial constraints on flight operations, while still not eliminating traffic conflicts. There is today great waste and misuse of airspace.

The SC-155 airspace management concept, which could be in place in less than 20 years, will allow flight operators to choose the most efficient routing: direct flights, trajectory cruise climb, best weather tracks, dynamic flight planning - all improvements which our present Flight Management Systems, already in our aircraft today, are capable of, but which we cannot implement because the ATC system of today will not allow it. The present ATC system cannot meet our needs on a global basis, but with the use of satellites and some automation we may now begin to create the Airspace Management System that can.

As may be expected, preliminary cost studies, which were part of the SC-155 effort, show that a global aeronautical satellite system is not inexpensive. But they did show that even for the most sophisticated, global coverage system - providing safe, dependable and accurate communications, navigation capability and airspace management for all segments of aviation - the total cost is about the same as for just one of the international airports planned today, in Denver or Tokyo or London. It is also about the same as one year's worth of airline orders for new aircraft - or the same as the balance in the U.S. Aviation Trust Fund.

A homogeneous system such as outlined by SC-155 will also have great benefits: present, operationally costly systems may be obsoleted, user access to services and to airports will be improved, fuel, aircraft and human resources will be better utilized and the traveling public will see even safer, more dependable transportation. Many of these new aviation systems could - and should - be managed by the air transport industry.

Most of what I have stated here concerns the global en route traffic, national and oceanic, but it is clear that much needs to be done also to increase airport capacity and terminal area efficiency and safety. SC-155 recognized that the terminal areas represent a larger, more varied problem picture justifying a separate study.

I am happy to see that much of what has been proposed in SCC-155 is already part of the FAA Research, Engineering and Development Plan and the National Airspace Plan. Especially the NAS Plan serves as a very important transition into the future, for example through the Advanced Automation System. It is tragic, however, that the good of this plan is not allowed to be implemented, as Congress and the Administration continue to deny the intended use of the Aviation Trust Fund. The airspace users contribute to this fund for the improvement of the airspace we use, rightly we should have more of a say in how it is allocated. Right now this is taxation without representation; do we need another tea party?

Another obstacle has been put in the way of reason. SC-155 made a study of whether the proposed satellite services would fit within the existing aeronautical L-band and concluded that it would be a tight fit. Then the Federal Communications Commission in a recent ruling shocked the aviation community by removing 96% of this frequency spectrum earlier set aside for exclusive use by aviation safety services. These frequencies had been allocated by the ITU World Administrative Radio Conference for exclusive aeronautical use in anticipation of global aviation satellite services. The FCC action is an insult to WARC and to the aviation community. We strongly support every effort by the FAA to appeal the FCC decision and we encourage Congress to make its own review of the ruling.

The satellite communications, navigation and surveillance systems envisioned in SC-155 and in the FAA Plans must be allowed to come to an implementation. To deny them is to stop aviation from moving into the 21st century.

Thank you, Mr. Chairman.

ULF R. C. GUSTAFSSON
UNITED AIRLINES

JOB TITLE: STAFF ENGINEER - AVIONICS

EDUCATION: ROYAL INSTITUTE OF TECHNOLOGY, STOCKHOLM, SWEDEN, MSEE 1963

EXPERIENCE: Mr. Gustafsson joined United Airlines in 1968 in the Communications Engineering section. He was involved in a wide variety of projects, given a wide exposure to all areas of airline operations. He had a part in the NASA Two-Segment Approach project and was Project Engineer for the NASA Global Air Sampling Program. He is presently Project Engineer for the FAA/Bendix Traffic Alert Collision Avoidance System (TCAS II) evaluation program, in addition to other duties.

Mr. Gustafsson has participated in several industry committees dealing with air transport industry needs, regulatory concerns and new system introduction. He was active in RTCA SC-155 from its formation.

Before joining United Airlines, Mr. Gustafsson worked for SATT Electronics (Sweden) and the Boeing Company.

Mr. Gustafsson was born in Sweden; he immigrated in 1966 and became a U.S. citizen in 1978.

Mr. GLICKMAN. Well, some folks believe that the real critical problems with the air traffic control system for the next several years are going to be things involving collision avoidance and airplanes in terminal control areas, and I have heard from people that while satellite technology is important, it doesn't really deal with that problem very dramatically, that's a ground-based problem to deal with, and I wonder if you might comment on that—that is, the nuts and bolts problems at least of the American air traffic system of concentration of aircraft in a few terminal control areas and how the satellite system would relate to that.

Mr. THOMAS. Mr. Chairman, I'd like to take the first crack.

Mr. GLICKMAN. Specifically, I'm talking about, for example, the Aeromexico crash in Los Angeles and that particular problem.

Mr. THOMAS. We do not think that the satellite systems will replace terrestrial systems in busy terminal areas. It makes absolutely no sense to send a communication up 22,000 miles and back again and waste all that time when you're talking to an airplane that's in sight or 5 miles away or so either for expense or time.

So we see a continuation of terrestrial systems that we hope will be interoperable and compatible with the satellite system so you won't have to carry two sets of avionic equipment. So we'll still use terrestrial systems of communications, navigations, and surveillance in the terminal areas.

Now where the satellites really will play a major role is places where the present line of sight systems simply cannot cover, below the line of sight and at the higher altitudes and in the areas of sparsely populated—over oceans, deserts, mountains, and so forth—where it's just impractical to put in the present line of sight systems.

Therefore, we see a merging in of the satellite technology, and it will be useful to provide communications, navigation, and surveillance services at many airports which would never afford the present expensive ground-based systems, because you can do it with satellites, but it cannot take the place in the very heavy terminal areas of very low weather approaches—the New Yorks, Chicagos, Atlantas, and so forth.

Any other members like to add to that?

Mr. GLICKMAN. So what you're saying—let me just understand it. What you're saying is, the applicability of this system to keep traffic from cataclysmic events at, let's say, major terminal control areas is probably something that will always have to be done with ground-based type systems, but that this system would have great usefulness not only in the areas of traveling long distances over oceans but may have usefulness at rather isolated type airports that one maybe could put in some sort of receiver for a satellite-based system that would be far cheaper, for example, than putting in—I don't know—an ILS or other forms of systems that were ground based, so the pilot would know precisely where an airport would be located because of the satellite-based navigation system.

Mr. THOMAS. For example, Mr. Chairman, we've got—what?—3,500 lighted and paved airports. I think the NAS plan calls for 1,200 MLS systems to be installed finally. That means you've got only 1,200 instrument approach facilities for at least 7,000 or 8,000 possible runway ends.

The satellite systems will give you an instrument approach capability of a sort—let's say 200½ or better—to each one of those runway ends, and it will give you instrument approach capabilities to locations which would never dream of having them otherwise. So, therefore, we just immediately open up a whole new area that would almost be impossible to cover in those lower density airports.

However, when you get to very high traffic volumes, then we need to keep our present terrestrial systems in.

Mr. GLICKMAN. I want to talk to you—you didn't speak about costs, at least in the summary; you may have spoken about them in the full report. I wonder if you could give us some idea of the initial effort that you think needs to be expended and long-term costs that you think will be incurred.

Mr. THOMAS. We had a great deal of work on costs and cost/benefits. It was under Mr. Gorham as chairman of the Transition/Economics Working Group. Mr. Gustafsson was the actual head of the small group, or smaller group, that worked together and ran computer programs out our ears, I guess, on the costs and benefits, and I'd like to ask Mr. Gustafsson to make some remarks on the costs.

Mr. GUSTAFSSON. The cost/benefit study that we were able to make within the framework of SC-155 with very limited resources was, by necessity, sketchy, and to present it in the best way in the report, we have both the methodology and the raw data available.

We made some coarse estimates of benefits and costs, and really, generally, what it shows is that the costs are worthwhile. The benefits are there for all segments of both users and providers—the FAA and other traditional providers as well as each user group.

The validity of the individual numbers is maybe something that can be questioned. We are not saying that what we presented is something we don't believe in, it is simply that with the resources we had, we could only sort of skim the surface of it.

In my prepared statement, I have said that, as may be expected, preliminary cost studies which were part of the SC-155 effort show that a global aeronautical satellite system is not inexpensive. But these studies did show that even for the most sophisticated system, with full global coverage, providing safe, dependable, and accurate communications, navigation capability, and airpace management for all segments of aviation, for this system the total cost, when put in perspective, is about the same as for just one of the international airports now planned in Denver, Tokyo, or London.

Mr. GLICKMAN. So what are you talking about—$5 billion?

Mr. GUSTAFSSON. In that order, yes, and it's also about the same as 1 year's worth of airline orders for new aircraft or about the same as we now have in the U.S. trust fund.

Considering the total expenses on air transportation around the world, it is maybe not a big figure. Considering that it has to come from global contributors, it may be a big figure.

Mr. GLICKMAN. Well, I mean, that cost is substantially less than the costs that I would initially have feared to do this kind of thing.

Mr. GUSTAFSSON. There is R&D costs that we did not take into account. We took into account the actual implementation of a system——

Mr. GLICKMAN. And how much are you talking about in terms of R&D?

Mr. GUSTAFSSON. That is a very nebulous figure to get hold of, and I think it should be studied further to determine what that number would be.

It should be remembered that what we are talking about in SC-155 are new technologies to aviation, but they are technologies that have been proven in other applications—namely, space systems and automation—and therefore there is no basic research that we talk about, it's application research.

Mr. GLICKMAN. Hm-mm.

Yes, Mr. Thomas.

Mr. THOMAS. Mr. Chairman, I'd like to add that one of the reasons that costs may be less than you expected, we assume that the military GPS system of 18 satellites plus the 3 spares would be funded and be in place, and we only took into account funding of additional satellites that might be necessary—for example, we think 24—to provide complete global coverage for civil type aircraft. So a large part of that navigation cost, we assume, has already been borne by the military.

In the event of commercially furnished navigation systems, which has been proposed, we did not take that into account as a cost.

So, basically, we were looking at communications, or you could initiate communications perhaps by rental or commercial use. So we don't think the startup costs and the evolution need be very expensive, considering the amount of satellite capability that exists now.

Mr. GLICKMAN. Well, I would just make a couple of points. Then I'm going to turn it over to Mr. Lewis. One is, we have an enormous amount of funding—funds in the airport trust fund, and they're just not being spent. I think it's a fraud on the American consumer and member of the traveling public and user of airplanes, and there are pools of money that are accumulating every day that can and should be used for safety and navigational purposes, and so I'm not sure that the money isn't available if we finally get off this kick of using it to make our deficit look lower rather than using it for the purposes that it was intended, and one of these days this and all administrations will get the message when we begin to have some serious catastrophes in this country, and then we'll be spending that money like there was no tomorrow.

But the other side of the coin is that this country has focused on some of the short-term problems, and they're quite serious in terms of basically keeping airplanes from crashing into each other and some of the today-type problems in the system itself—enough competent controllers, and problems of deregulation, and what ground-based system equipment should airplanes contain to keep those problems up, and I think our big challenge in all of this is to keep our eye on the 21st century as well. That's hard to do when you've got a lot of these short-term problems because, even though I say $5 billion may not be as high as I was talking about, it's still an awful lot of money when you consider other financial needs of our Government and needs not just generally but also in the air safety and navigational related areas.

But I will have to read through your entire report. I think you've done a tremendous service to keep this issue alive, and I think we

need to move ahead on satellite-based technology in this country for navigation and communication purposes. It's spinoffs not only into navigation, but the general communications area is dramatic in terms of how we will talk to each other, not just from airplane to ground but from person to person, and we're going to be hearing from the FAA later on in the day, and I think this is something that institutionally may be troublesome in terms of how to meld this with everything else that we're doing. But I think you've done a tremendous service in approaching the issue from a technical point of view.

Yes, sir.

Mr. THOMAS. I'd just like to add a little more clarification on costs. We did not include the terminal area costs since they are terrestrial, continue to be terrestrial, the same in either system, and those costs will continue but were not part of the $5 billion, and I just wanted to clarify that.

My second point is, you ask how much R&D. We got considerable. The GPS system is not here yet, and I don't know quite the date since the shuttle mishaps, but even when it is there, as it exists today, it is not acceptable as a sole means of navigation. By sole means, you could rely on it without having any reliance on anything else. That can be changed. One of the ways I said was the additional six satellites.

So there's considerable work that must be done within the FAA and the industry and the community to make ready to use these things that we see and know can be done in the community, but they're not here today.

Mr. GLICKMAN. OK. Thank you.

Mr. Lewis.

Mr. LEWIS. Thank you, Mr. Chairman.

I also want to congratulate you, gentlemen, on the fine work you've done over the past 2 years. I do have a few questions I would like to ask.

Your committee did conclude that NAS will not meet all user requirements—for example, where a flight is restricted due to limited ATC capabilities. Can you identify some of the limitations and explain how a satellite system can overcome this?

Mr. THOMAS. Yes, sir. The satellite system will do nothing as far as giving us more controllers, or better trained controllers, or better computers. That is part of the system. What it will do will give us information in spaces that line-of-sight facilities do not cover. For example, a navigation facility or communication facility usually goes out line of sight, and that will be 1,000 feet at 30 miles, and anything below that neither gets navigation or communications. This will see down everywhere. So fundamentally it will just increase the amount of airspace which information will be available to the facilities.

The burden will still be upon, let's have a good navigation—I mean a good controller force, a good computer backup for the air management system, and this is why we say it's very fundamental that we go ahead and improve those things, because the satellite services will simply put more burden on them, not decrease it, because it will give them more information, more traffic to handle.

Mr. LEWIS. Do you feel that the satellite system will be a sole precision system?

Mr. THOMAS. A sole system, no, sir.

Right now, due to the time delay in just exchanging information from an aircraft which is on approach, let's say, at 120 knots, up to 22,000 miles and back, he's covered quite a distance before he gets his last position. We think the very accurate precision landing has to be done with something on the ground. This is why we're still looking at MLS, we're still looking for terminal communications, we're still looking at terminal surveillance of some sort.

So we do not expect to see the satellites supplant the ground facilities at busy airports. We do expect them to be quite adequate at the less busy airports where we're otherwise an aerial service, because we won't go down to the same weather minimums.

Mr. LEWIS. I'm intrigued by your comment twice now about the time delay between the satellite and back down. How long does it take to transmit to the satellite and back?

Mr. THOMAS. About four-tenths of a second. Isn't it something like that? It's fraction of a second, but that's a long time.

Mr. LEWIS. Have you ever heard an air traffic controller talk?

Mr. THOMAS. Yes, sir.

Mr. LEWIS. It takes you at least that to try to decipher what he said.

Mr. THOMAS. I used to be one, sir.

Mr. LEWIS. Well, then, you know what I'm talking about.

Mr. THOMAS. Yes, sir.

Mr. LEWIS. I just don't understand where that would be such a—four-tenths of a second—you can't react that fast.

Mr. THOMAS. Oh, I'm talking about a navigation system, not communications.

Mr. QUINBY. It's not just the voice communications, sir, it would be the exchange of data at relatively high speeds and navigation information, and here the fraction of a second begins to influence the amount of data flow that you can use and the rate at which you can use it.

Mr. LEWIS. All right.

I'd like to discuss a little bit about the evolutionary process and what it's going to mean to the user, and particularly as it relates to general aviation. I don't know how much your committee looked into the general aviation area. But is a pilot going to have to carry in his avionics package an ILS, and MLS, and satellite system all at one time? What's going to happen to Loran-C, and VOR—this sort of thing?

I feel that there should be some concern about this and that today you go from one system to the other, and you're required to do this as one system becomes available and another one becomes obsolete, or because of factors it's made obsolescent by just cutting it out because it costs too much, and the general aviation pilot—the air traffic controller, he can't get in because his system is not capable or compatible. What's your response to this?

Mr. QUINBY. Thank you, Dave.

I am particularly proud to have chaired the operations working group, which was composed not only of the major airline representation, but the Aircraft Owners and Pilots Association's staff mem-

bers participated extensively, the National Business Aircraft Association was very supportive of the work of SC-155, we had the Regional Airline Association and the Helicopter Association International participating on behalf of their constituencies.

The task of the operations working group was to achieve consensus, if possible, compatible disagreement if consensus was not possible, and all of these agreements took place over a period of 11 meetings during 1984.

The results of those meetings are formalized in an appendix to the report, and I would invite your attention to it. It's appendix D, as a matter of fact, and it has all of the statements of operating requirements of all of the users organized so that the agreements and disagreements are quite clear.

This was completed in 1984, and most of 1985 was spent putting all these together with a number of meetings of other working groups and then the working group of the whole to come up with the first draft of the final report.

I'm proud to say that the operations working group went back after having gone through that, and early in the present year we went over all those statements of operating requirements, and the application of the technologies, and the costs, and the transition considerations hadn't changed the statement of requirements on which the report is based, and the general aviation operators and users of the airspace are, in my opinion, very fairly represented in this report. The transition considerations have them in mind, and I think Mr. Gustafsson, who spoke very effectively for the air transport part of the industry, would agree with me on this statement.

Mr. LEWIS. Also, you are convinced—I haven't had time, certainly, to read appendix D, but you're convinced then, Mr. Quinby, that general aviation does have a part and was a great consideration in the evolutionary process and that their concerns and considerations were taken into consideration, or is it just reported that they objected and nothing else was done about it?

Mr. QUINBY. No, sir. They were very much a part of the consensus that was achieved by the committee, and I think that is probably the most significant accomplishment of SC-155.

Mr. LEWIS. OK. I would also like to ask the question, I guess, Mr. Thomas or anyone else on the committee, that your independence surveillance on the space-based primary radar—your conclusion was it would not be available?

Mr. THOMAS. I'd like to refer that to Dr. Kramer, if I may.

Mr. KRAMER. Mr. Lewis, we concluded that you couldn't count on it being available, because we were in a position of extrapolating technology development over the next decade to 15 years.

If such space-based radar of adequate size were available—were to become available for implementation in 2010, it would certainly have to be well established technology by the year 2000, and, standing here in 1986, it is difficult to project with confidence that such precise structures of adequate size would be available from a technology standpoint in the timeframe where they would be needed to be implemented fully by 2010.

We did not ignore the technology, and we discussed it at some length, and I think we concluded that there might be tremendous

benefits associated with such a system if it were available, but one could not count on its being available.

Mr. LEWIS. I see.

How would you describe to the subcommittee how an airspace management system would operate?

Mr. THOMAS. Mr. Gustafsson was the——

Mr. LEWIS. I'm still concerned about general aviation.

Mr. THOMAS. Yes. I'd like Mr. Gustafsson to speak first and then make sure we cover the general aviation.

Mr. GUSTAFSSON. Thank you, David.

The basic idea behind the airspace management system is that its first and primary service would be separation assurance, keeping aircraft separated, and it would do so by monitoring the traffic.

The emphasis in the airspace management system, as we envisioned it, was on the surveillance system, not on navigation as it is today, navigation capability. Especially over the oceans, the separation assurance is based on navigation capability, not on surveillance, proper knowledge by a managing agency where everybody is.

We agreed that to ensure the separation assurance the participation was the most important part, and this is where we had the most discussion among the users and where I think we came to an amiable understanding among us, including general aviation.

The end result was that we devised two systems where the first one was based essentially on evolution of the NAS plan which would use for surveillance automatic dependent surveillance, as it was called, which is position reporting from a rather sophisticated navigation system on board the aircraft through a satellite-based communication system.

Now we quickly recognize that this is not something which general aviation would like to put in all the aircraft. So the participation in that sort of surveillance system would be small unless it was limited to oceanic areas where it's a natural, or high altitude areas where mostly the well equipped aircraft fly.

The second system that we devised was the one that increased participation for the general aviation by devising a transponder type system similar to what we have today in the A or C transponder, where you would have a reasonably inexpensive device which did not rely on any way you'd navigate or communicate in a small airplane, it could still be seen by the airspace management system, and other aircraft could be made to avoid it.

The core of the airspace management concept was this monitoring rather than controlling. It has to know intent of aircraft only on the short period, not for the whole flight.

We admit that the airspace management system as an idea was an idea that was expressed in SC-155. It is one that appealed to most users—to all the users, I should say, and something that we should try to build on.

The present air traffic control system philosophy will not work in the long run. We already see it giving us difficulties with capacity and efficiency, and we need something better, and this is the time to do it, to change over to a more forward, modern thinking than the air traffic control system is built on.

Mr. THOMAS. Mr. Lewis, I'd like to add that we have a very short statement in the report I would like to read which I think describes it, on airspace management.

Mr. LEWIS. OK.

Mr. THOMAS. It says:

> In response to the widening divergence of aircraft characteristics and capabilities, it is expected that aircraft management will vary much as it does today. There will continue to be a system of airspace management with various degrees of control. Aircraft will operate with a variety of pilot proficiencies, equipment capabilities, and operating requirements. Areas where all aircraft must operate under some level of control will continue to be specified where traffic volume or other operational requirements dictate. Changes in airspace demand will dictate corresponding alterations in the management of the airspace. Traffic volume increases or shifts in airspace, airport access will result in procedural limitations and/or equipment requirement similar to those in use in today's high density airports.

That's contained in paragraph 2.2, and it goes on.

This was looked at very carefully by AOPA, NBA, and others. It took us quite a while to come to these words, as one might imagine, and I'd also just like to add that Mr. Gustafsson, Mr. Quinby, and myself are all general aviation pilots, so we're aware of the fact we want to continue to fly without excessive avionics.

Mr. LEWIS. Thank you very much, Mr. Thomas.

Thank you, Mr. Chairman.

Mr. BROWN. Mr. Glickman, did you get a chance to——

Mr. GLICKMAN. Yes, I did.

Mr. BROWN. Gentlemen, I apologize for being detained in another committee, and I very much wish I had heard all of your testimony. I have reviewed the written testimony and am going to study it much more carefully. I appreciate your helping us out here this morning on this very important subject, and I want to assure you of my personal interest in advancing the utilization of the best available technology for the benefit of both general aviation and the aviation industry as a whole as quickly as we can.

Having said that, I have no further questions, and you may be excused.

[The prepared statement of Mr. Brown follows:]

HONORABLE GEORGE E. BROWN, JR., CHAIRMAN

SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS
COMMITTEE ON SCIENCE AND TECHNOLOGY
U. S. HOUSE OF REPRESENTATIVES

SEPTEMBER 24, 1986

# USE OF ADVANCED SATELLITE SYSTEMS FOR GLOBAL AIR TRAFFIC CONTROL AND NAVIGATION

TODAY THE SUBCOMMITTEE WILL TAKE A LONG-RANGE LOOK AT THE FUTURE OF AIR TRAFFIC CONTROL, A SUBJECT WITH PROFOUND IMPLICATIONS FOR THE SAFETY AND EFFICIENCY OF AIR TRAVEL.

OF COURSE, THE FAA IS PRESENTLY INVOLVED IN A MASSIVE UPGRADE OF THE CURRENT AIR TRAFFIC CONTROL SYSTEM. THIS EFFORT, WHICH IS PROJECTED TO COST OVER $12 BILLION, REPRESENTS A MAJOR STEP FORWARD TOWARD AUTOMATION, CAPACITY IMPROVEMENT, RELIABILITY AND SAFETY.

SO, WHY ARE WE CONCERNED AT THIS POINT ABOUT WHAT MAY COME NEXT? THE ANSWER LIES IN THE FACT THAT FAA'S NAS PLAN, AS EXTENSIVE AS IT IS, STILL FALLS SHORT OF PROVIDING ALL THE CAPABILITIES THAT USERS WANT. ALSO, TECHNOLOGY, ESPECIALLY SATELLITE TECHNOLOGY, HAS MARCHED ON SINCE THE PLAN WAS DEVISED IN 1981, CREATING A WEALTH OF NEW POSSIBILITIES.

HON. GEORGE E. BROWN, JR. -- PAGE TWO

OUR HEARING TODAY IS INTENDED ONLY TO INTRODUCE THE NEEDS AND OPPORTUNITIES AND TO BEGIN THE PROCESS OF PLANNING FOR THE NEXT GENERATION AIR TRAFFIC CONTROL SYSTEM. I DO NOT EXPECT TO BE ABLE TO REACH ANY FINAL CONCLUSIONS. BUT WE MUST BEGIN TO EXAMINE THE POSSIBILITIES AND EXPLORE THE ISSUES.

AT THIS POINT, I WILL RECOGNIZE OUR RANKING REPUBLICAN, TOM LEWIS.

. . . . . .

OUR FIRST GROUP OF WITNESSES REPRESENT THE RADIO TECHNICAL COMMISSION FOR AERONAUTICS, A GROUP LONG INVOLVED WITH PLANNING FOR FUTURE AIR TRAFFIC CONTROL SYSTEMS. IN THIS INSTANCE, RTCA HAS CONDUCTED A THOROUGH EXAMINATION OF THE UN-MET NEEDS OF THE NAS PLAN AND THE OPPORTUNITIES FOR NEW TECHNOLOGY TO MEET THESE NEEDS.

Mr. THOMAS. Thank you, Mr. Chairman.

Mr. BROWN. Our next witness this morning is Mr. Carl Palmer, associate director, Information Management and Technology Division of the General Accounting Office.

Mr. Palmer.

Thank you for being here this morning, Mr. Palmer. We're looking forward to your testimony, and you may proceed in any way that you wish. The full text of your statement will appear in the record, of course, if you should omit some small part of it by accident or otherwise.

**STATEMENT OF CARL R. PALMER, ASSOCIATE DIRECTOR, INFORMATION MANAGEMENT AND TECHNOLOGY DIVISION, GENERAL ACCOUNTING OFFICE, ACCOMPANIED BY DOUGLAS CANNON, GROUP DIRECTOR; AND ALLEN LI, GROUP DIRECTOR**

Mr. PALMER. Thank you, sir.

I will read most of the statement, if it's all right with the chairman.

Good morning. We appreciate this opportunity to comment on the potential use of satellite technology for air traffic control and navigation. We believe this potential use is best addressed within the context of this Nation's airspace system as far as our comments.

As you know, the Federal Aviation Administration developed and issued the National Airspace System plan in 1981 in a major effort to modernize the Nation's airspace system, including air traffic control and navigation.

The NAS plan is primarily based on ground-based systems and gives minimal consideration to satellite technology because, in FAA's opinion, satellites were not cost-effective when the plan was developed nor could they be operational by the time the upgraded ground-based systems were to be in place by the early 1990's.

In 1983, FAA requested RTCA to look beyond the NAS plan and assess the value of satellite and other technologies for civil aviation. The commission's recent draft report is also supposed to provide a basis for U.S. input into an international committee that is evaluating the potential use of satellites for air traffic control on a global basis.

Based on our several studies to date on the NAS plan, our preliminary work in evaluating the use of satellite technology, and our initial assessment of the recent draft report by RTCA, it appears that satellite technology has advanced rapidly and may be more available and cost-effective than FAA believed in 1981. At the same time, the potential for satellite technology has improved, it has become increasingly apparent that the NAS plan may not deliver the systems and the benefits expected at the cost expected or within the time frame expected. Consequently, this may be a good time for FAA to reexamine its plan.

FAA has some research and development projects which, if focused properly and actively pursued, could serve to clarify the role of satellite technology. However, much work needs to be done, and these projects are largely unfunded. The emphasis should be on how and when satellite technologies may be properly integrated

into the plan, the end objectives of system modernization, and any needed changes in FAA's investment plans and in its R&D programs.

As you know, Mr. Chairman, the communications, navigation, and surveillance systems are integral parts of the Nation's and the international airspace systems and the NAS plan. Presently and in the NAS plan, they are predominantly ground-based line-of-sight systems.

When combined with the agency's new, advanced automation systems, CNS systems are expected to produce large benefits for both users and FAA. Most user benefits, such as fuel savings, would come from the users' ability to select and operate on routes and altitudes of their choosing in the higher areas of the airspace. Most FAA benefits, such as improving the effectiveness and efficiency of air traffic controllers, would come from improved communications and increased ground-based automation, including increasingly automated air traffic control decisionmaking.

In 1982, the Office of Technology Assessment issued a report on FAA's NAS plan. The report concluded that satellites had considerable potential for communications, navigation, and surveillance, and that FAA may have prematurely written off the use of satellite technology.

A 1984 FAA report to the House Appropriations Committee restated their belief that it might be as much as 30 years before the satellites needed to support surveillance could be in place, if at all. The OTA, however, had concluded that satellite technologies warranted reexamination if the NAS plan schedule slipped or if benefits as compared to costs did not materialize as FAA had projected.

It appears that the current NAS plan is not going to deliver the systems and the benefits expected at the cost expected or within the time frame expected. While operational and staffing problems have grown, the schedules of most major programs have slipped because of technical and management problems. FAA's benefits are or will be much lower than originally estimated, and cost estimates have risen substantially.

In particular, those key NAS plan automation features which, when combined with the planned CNS systems, are expected to deliver most of the user fuel savings in FAA controller productivity benefits have slipped 5 to 10 years and will not be fully implemented until after the year 2000, if at all.

Our July 1986 report questioned the technical and operational feasibility of one of the systems in this program, the advanced automation system, and, as you know, Mr. Chairman, we testified to this committee in April on that work.

To date, FAA has not demonstrated the technical and operational feasibility of this system's advanced automation features, the so-called AERA functions, and is having difficulty in defining how those AERA procedures can be developed with ground-based systems.

The 1981 plan estimated that, beginning in 1989, this system was supposed to allow more flexible and direct routes in the higher areas of the airspace, thus providing fuel savings to users using that airspace. It now appears that the first installment of that such capability may not be available until as late as 1997.

We have increasing concerns with some of the plan—technical and operational performance of some of the FAA's planned CNS systems, but, overall, as time frames and costs increase, it becomes more questionable whether FAA benefits expected from the NAS plan will exceed costs.

Our work to date indicates that by the year 2000 the NAS plan will now cost $16.5 billion instead of $11.7 billion originally estimated in 1981. Overall, the discounted FAA benefit estimates through the year 2000, which are currently being reexamined, have fallen from $24.5 billion to about $16.5 billion.

Perhaps more important, as identified in RTCA's recent report, even if the NAS plan were to be fully and successfully implemented, it would not meet many of the aviation community's CNS needs for the next 25 years. For example, the current and planned CNS systems do not provide complete coverage of the earth's surface because of their short-range line of sight from the ground, which rises away from the curvature of the earth. This leaves an increasing gap in coverage underneath the radar's or other communication device's beam.

Additionally, as mentioned earlier, the NAS plan, if successfully implemented, will provide fuel savings benefits via direct routes to only those users, primarily the major air carriers, who fly in the higher areas of the airspace. It leaves a large number of commuter, business, and general aviation without substantive improvement in their VFR/IFR coverage and services.

Based on our limited assessment, satellite CNS technologies appear to be the only cost-effective way to address these limitations and to satisfy many user needs. Satellites essentially provide coverage down to the Earth's surface because of their strategic, more comprehensive, look-down view.

For example, such coverage may improve the controller's ability to better identify potential aircraft conflicts in the lower areas of the airspace and communicate warnings to the aircraft which could be critical to improved airspace safety. Satellites may further facilitate the location of downed aircraft, thus improving search and rescue operations.

These are just examples, sir; there are other things. I think the RTCA study does a much better job of explaining these advantages than these examples.

Finally, we are concerned that, if implemented, the NAS plan may well constrain options for future cost-effective transitions to the use of satellite technology. For example, the currently planned advanced automation system is oriented to ground-based data processing and automated decisionmaking. This type of system does not readily appear to be operationally and economically extendable to a satellite-based system that is conducive to more shared data processing, automation, and decisionmaking with the aircraft.

In addition, because of power and antenna limitations, it does not appear at this time that the plan's new ground-based data link system for communications will be able to economically operate with satellites.

RTCA's work is notable because it presents a different view on future airspace management. The commission concluded that the future airspace management system should, with more flexible

real-time monitoring, permit each flight to operate on its most favorable and fuel efficient path without intervention except as necessary to avoid severe weather or collision with another aircraft. This represents a substantive change in control philosophy from either the current close control to fixed altitudes and preset routes or the currently planned automated control to preset flight plans. In addition, the commission proposed that future CNS systems should provide coverage from the Earth's surface to 70,000 feet and eventually even higher.

The benefits of the commission's proposal rely almost totally on the extent to which this airspace management concept can be achieved.

The commission also concluded that, even if fully and successfully implemented, the NAS plan would not provide the capabilities necessary for the future airspace management system. For example, it said the plan would not meet all user requirements, such as coverage of low-altitude areas, landing of aircraft in areas that do not have precision landing capabilities, and control of airspace where flight is restricted due to limited CNS capabilities.

The commission concluded that the use of satellite CNS technology along with automation technology appears to be the most cost-effective way to overcome most air traffic control system deficiencies and satisfy users' unmet CNS needs.

The commission's work also included an assessment of the operational, economic, and technical feasibility of alternative technology, including satellite technology. The commission observed that satellite technology would likely become cost effective in the near future.

The commission assumed that since the NAS plan would deliver interim capabilities and benefits in a timely fashion, the plan should not be delayed to wait for the benefits of a new airspace management system. The NAS plan, it assumed, would be flexible enough to accommodate the new satellite technology as it became available in the near future.

We believe that the commission's assumption of timely safety and economic benefits from the NAS plan may not be valid under existing conditions—judging from the current status of many projects in the plan.

As mentioned earlier, our review of existing documents has shown that the schedules of most major programs have slipped, the FAA benefits are much lower, and the cost estimates have risen substantially. Estimates of user benefits are currently being restudied.

Also as mentioned earlier, we believe that it is not clear as to whether the NAS plan has sufficient flexibility to economically or technically accommodate satellite technology in a timely manner. Therefore, we believe the commission's assumption concerning the timeliness and benefits of the NAS plan projects is somewhat of a limitation.

While we think the study is an outstanding contribution, we can't really agree with the commission's assumption that the NAS plan, as currently structured, should proceed without reexamination of its merits as compared to satellite system alternatives.

We think FAA has the opportunity to reconsider satellite technology. We have reported several times over the past decade on the need to evaluate satellite technology. In a March 1978 report, we called for a new direction in navigation systems planning with the advent of DOD's global positioning system, a satellite-based navigation system. In 1979, we reported that FAA needed to increase its efforts in evaluating the use of this system for civil aviation. Further, in May 1984, in June 1985, we suggested that there may be advantages to taking a clean sheet approach to evaluating the potential of alternative integrated air traffic control system architectures, including those based on satellite CNS technology.

It appears that the basic elements for providing enhanced satellite capabilities will soon be available. For example, the GPS has planned to provide three-dimensional coverage beginning in 1991, and that does make an assumption about the inability for shuttle deliveries.

Another satellite service with the potential to provide navigation and surveillance capabilities may be available in the mid-1990's. Satellite voice and data communication systems are currently available, and others will soon be available.

Although we believe the use of satellite CNS systems may satisfy more user needs, important economic, technical, and institutional questions must be answered before implementing this technology. These must be thoroughly examined before the aviation community can determine the extent to which these systems can be used to perform the primary CNS functions.

For example, several potential barriers to the acceptance and implementation of satellite technology are its vulnerability to untimely notification of failure; vulnerability to jamming; its cost; acquisition, development, testing and integration questions; commercial service alternatives and the attendant liability and quality assurance questions; and the institutional problems of integrating it with international air traffic control.

We believe that, one, substantial and immediate commitment to our research, development, testing, and evaluation can overcome these problems; two, satellite CNS systems could provide better coverage and accuracy than ground-based CNS systems; three, satellite CNS systems could improve air traffic control over currently planned improvements, particularly in the areas of efficiency, such as traffic management and airspace utilization, and in safety such as aircraft separation assurance; and, four, satellite CNS systems can improve these services as well as expand them to most of the airspace and many more airspace users.

Both the positive and negative aspects of how to apply satellite technology to air traffic control need to be considered. The commission's study results, the advances in satellite technology, avionics, cockpit automation, and computer technology, and the slowdown and declining expectations in achieving the current NAS plan system modernization create, we believe, a window of opportunity.

That window of opportunity is available for Congress and FAA to take a new view of the NAS plan as a living document with the flexibility to evolve to meet the needs of the airspace users effectively and economically with changing technology. In that view, the plan becomes a step-by-step approach to upgrading air traffic

control systems in a way calculated to take advantage of emerging technologies that potentially offer better service at a better cost.

With the upcoming multibillion-dollar investment in trust fund decisions, we believe our statements today argue for an immediate and thorough reexamination of the potential use of satellite technology, including that technology's potential impact on the current NAS plan. Such a reexamination should include a full exploration of logical strategies for the transition of satellite and advanced avionics technologies to meet future air traffic control needs.

To be clear, we are not recommending either slowing down or stopping the NAS plan but simply a thorough reexamination and some caution on the commitments to the advanced automation system and CNS investment commitments.

FAA has some system studies in satellite technology projects—which we believe are presently largely unfunded—which, if focused properly and actively pursued, could clarify the future role of satellite technology and how it could be integrated into the current NAS plan. However, FAA will most likely have to place a much more immediate and greater priority on these research, engineering, and development efforts to solve the problems of using satellite technology effectively and economically in the air traffic control. Also, based on the results of this reexamination, Congress and FAA may want to modify or reconsider a number of programs in the current NAS plan.

That concludes my testimony, Mr. Chairman. We would be happy to answer any questions you or members of the subcommittee have at this time.

[The prepared statement of Mr. Palmer follows:]

UNITED STATES GENERAL ACCOUNTING OFFICE

WASHINGTON, D.C. 20548

FOR RELEASE ON DELIVERY

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WEDNESDAY, SEPTEMBER 24, 1986

STATEMENT OF

CARL R. PALMER, ASSOCIATE DIRECTOR

INFORMATION MANAGEMENT AND

TECHNOLOGY DIVISION

BEFORE THE

SUBCOMMITTEE ON TRANSPORTATION, AVIATION, AND MATERIALS

OF THE

HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

ON

USE OF SATELLITE TECHNOLOGY FOR

AIR TRAFFIC CONTROL AND NAVIGATION

Mr. Chairman and Members of the Subcommittee:

We appreciate the opportunity to comment on the potential use of satellite technology for air traffic control and navigation. We believe this potential use is best addressed within the context of the national airspace system. As you know, the Federal Aviation Administration (FAA) developed and issued a National Airspace System (NAS) plan in 1981[1] in a major effort to modernize the nation's airspace system, including air traffic control and navigation. The NAS plan is primarily based on ground-based systems and gives minimal consideration to satellite technology because, in FAA's opinion, satellites were not cost-effective when the plan was developed, nor could they be operational by the time the upgraded ground-based systems were to be in place by the early 1990s.

In 1983, FAA requested the Radio Technical Commission for Aeronautics to look beyond the NAS plan and assess the value of satellite and other technologies for civil aviation. The Commission's recent draft report[2] also provides a basis for U.S. input into an international committee that is evaluating the potential use of satellites for air traffic control on a global basis.

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[1]National Airspace System Plan (Federal Aviation Administration, December 1981).

[2]Draft Report of Special Committee 155, User Requirements For Future Communications, Navigation, and Surveillance Systems, Including Space Technology Applications (RTCA Paper No. 354-86/SC155-190, August 13, 1986).

Based on several studies to date on the NAS plan, our preliminary work in evaluating the use of satellite technology, and our initial assessment of the recent draft report by the Radio Technical Commission for Aeronautics, it appears that satellite technology has advanced rapidly and may be more available and cost-effective than FAA believed in 1981. At the same time the potential for satellite technology has improved, it is becoming increasingly apparent that the NAS plan may not deliver the systems and benefits expected, at the cost expected, or within the timeframe expected. Consequently, this may be a good time for FAA to re-examine its plan. FAA has some research and development projects, which, if focused properly and actively pursued, could serve to clarify the role of satellite technology. However, much work needs to be done and these new projects are largely unfunded. The emphasis should be on (1) how and when satellite technologies may be properly integrated into the plan, (2) the end objectives of the system modernization, and (3) any needed changes in FAA's investment plans and in its research and development programs.

## COMMUNICATIONS, NAVIGATION, AND SURVEILLANCE SYSTEMS ARE INTEGRAL TO THE NATION'S AIRSPACE SYSTEM

Communications, navigation, and surveillance (CNS) systems, integral parts of the national and international airspace systems and the NAS plan, are predominantly ground-based, line-of-sight systems. Communications systems provide the connectivity between he pilot and controllers and among controllers. Navigation systems provide aircraft position information to pilots and

facilitate landing. Surveillance systems provide the current aircraft position data to controllers.

When combined with the agency's new advanced automation systems, CNS systems are expected to produce large benefits for both users and FAA. Most user benefits, such as fuel savings, would come from the users' ability to select and operate on routes of their choosing in the higher areas (generally above 30,000 feet) of the airspace. Most FAA benefits, such as improving the effectiveness and efficiency of air traffic controllers, would come from improved ground-to-air and air-to-ground communications and increased ground-based automation, including increasingly automated air traffic control decisionmaking.

In 1982 the Office of Technology Assessment issued a report[3] on FAA's NAS plan. The report concluded that satellites had considerable potential for communications, navigation, and surveillance and that FAA may have prematurely written off the use of satellite technology. Also, the report noted that FAA excluded satellite CNS technology from its 1981 plan because, in FAA's opinion, satellites were not cost-effective at that time, nor could they be operational by the time the upgraded ground-based systems were to be in place in the early 1990s. A 1984 FAA report[4] to the House Appropriations Committee restated this

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[3]Review of the FAA 1982 National Airspace System Plan (OTA-STI-176, August 1982).

[4]The Mode S Program and Long Range Future Plans for Aircraft Surveillance (Federal Aviation Administration, June 1984).

belief and added that it might be 30 years before the satellites needed to support surveillance could be in place, if at all. The Office of Technology Assessment concluded that satellite technologies warranted re-examination if the NAS plan's schedule slipped or if benefits as compared to costs did not materialize as FAA had projected.

## CONCERNS WITH THE NAS PLAN

It appears that the current NAS plan is not going to deliver the systems and FAA benefits expected, at the cost expected, or within the timeframe expected. Operational problems have grown; the schedules of most major programs have slipped because of technical and management problems; FAA's benefits are, or will be, much lower than originally estimated; and cost estimates have risen substantially.

In particular, those key NAS plan automation features, which, when combined with the planned CNS systems, are expected to deliver most of the user fuel savings and FAA controller productivity benefits, have slipped 5 to 10 years and will not be fully implemented until after the year 2000, if at all. Our July 1986 report[5] questioned the technical and operational feasibility of one of the systems in this program--the Advanced Automation System. To date, FAA has not demonstrated the technical and operational feasibility of this system's advanced automation

[5]Air Traffic Control: FAA's Advanced Automation System Acquisition Strategy is Risky (GAO/IMTEC-86-24, July 8, 1986).

features and is having difficulty in defining how these procedures can be developed with ground-based systems. The 1981 plan estimated that beginning in 1989, this system was supposed to allow more flexible and direct routes in the higher areas of the airspace, thus providing fuel savings to users (primarily air carriers) using that airspace. It now appears that the first installment of such capability will not be available until 1997.

There also appears to be increasing concern about the technical and operational performance of FAA's planned CNS systems. Two come to mind. The first is the precision landing system. This system is supposed to deliver added airport capacity through more efficient landing approaches, as well as additional fuel and time saving benefits to users. The second is a new data-link, which is supposed to provide ground-to-air and air-to-ground digital data communications, thus improving controller productivity. The full implementation of these systems is also slipping toward the year 2000.

As timeframes and costs increase, it becomes more questionable whether FAA benefits expected from the NAS plan will exceed the costs. Our work to date indicates that through the year 2000 the NAS plan will now cost $16.55 billion instead of the $11.7 billion estimated in 1981. Overall, the discounted benefit estimates for FAA through the year 2000, which are currently being re-examined, have fallen from $24.5 billion to $16.5 billion.

Perhaps more important, as identified by the Commission's recent draft report, even if the NAS plan were to be fully and successfully implemented, it will not meet many of the aviation community users' CNS needs for the next 25 years. For example, current and planned CNS systems do not provide complete coverage of the earth's surface because of their short-range line-of-sight from the ground, which rises away from the curvature of the earth, leaving an increasing gap in coverage underneath the radar's beam. Additionally, as mentioned earlier, the NAS plan, if successfully implemented, will provide fuel saving benefits via direct routes only to those users (primarily major airline carriers) who fly in the higher areas of the airspace. This leaves the large number of commuter, business, and general aviation without any substantive improvement in coverage or services.

Based on our limited assessment, satellite CNS technologies appear to be the only effective way to address these limitations and to satisfy most user needs. Satellites essentially provide coverage down to the earth's surface because of their strategic, more comprehensive, look-down view. For example, such coverage may improve the controllers' ability to better identify aircraft conflicts in lower areas of the airspace and communicate warnings to the aircraft, which can be critical to improved airspace safety. Satellites may further facilitate the location of downed aircraft, thus improving search and rescue operations.

Finally, we are concerned that if implemented, the NAS plan may well constrain options for future cost-effective transitions to the use of satellite technology. For example, the currently planned Advanced Automation System is oriented to ground-based data processing and automated decisionmaking. This type system does not appear to be operationally or economically extendable to a satellite-based system that is conducive to more shared data processing, automation, and decisionmaking in the aircraft. In addition, because of power and antenna limitations, it does not appear at this time that the plan's new ground-based data-link system for communications will be able to economically operate with satellites.

## THE RADIO TECHNICAL COMMISSION FOR AERONAUTICS PROVIDES A DIFFERENT PERSPECTIVE ON AIRSPACE MANAGEMENT AND SYSTEM ARCHITECTURES

The Radio Technical Commission for Aeronautics is a long-standing association of U.S government and private aeronautical organizations. The Commission does research to develop technical solutions to aeronautical problems involving the application of electronics and telecommunications. At FAA's request, the Commission established a special committee in July 1983 to develop representative civil user views of the needs and requirements and forecasts of airspace conditions for technological applications, including satellite technology, for at least the next 25 years. The Commission was also to assist the U.S. Government in formulating a position on CNS user needs as input to an international committee examining a similar issue. The Commission looked beyond the NAS plan and outlined a

transition into possible but not yet available systems. Essentially, the Commission's work assumed that the current NAS plan would become operational and deliver benefits by the early to mid-1990s.

We believe that the Commission's work is notable because it presents a different view on future airspace management. The Commission concluded that future airspace management systems should, with more flexible real-time monitoring, permit each flight to operate on its most favorable and fuel-efficient path without intervention, except as necessary to avoid severe weather or collision with another aircraft. This represents a substantive change in control philosophy from either the current close control to fixed altitudes and preset routes or the currently planned automated control to preset flight plans. In addition, the Commission proposed that future CNS systems should provide coverage from the earth's surface to 70,000 feet and eventually even higher. The benefits of the Commission's proposal rely almost totally on the extent to which this airspace management concept can be achieved.

The Commission also concluded that even if fully and successfully implemented, the NAS plan would not provide the capabilities necessary for the future airspace management system. For example, it said the plan would not meet all user requirements, such as (1) coverage of low altitude areas, (2) landing of aircraft in areas that do not have precision landing capabilities, and (3) control of airspace where flight is

restricted due to limited CNS capabilities. The Commission concluded that the use of satellite CNS technology, along with automation technology, appears to be the most effective way to overcome most air traffic control deficiencies and satisfy users' unmet CNS needs. The Commission's work also included an assessment of the operational, economic, and technical feasibility of alternative technology, including satellite technology. The Commission observed that satellite technology would likely become cost-effective in the near future.

The Commission assumed that, since the NAS plan would deliver interim capabilities and benefits in a timely fashion, the plan should not be delayed to wait for the benefits of the new airspace management system. The NAS plan, it assumed, would be flexible enough to accommodate the new satellite technology as it became available in the near future.

We believe that the Commission's assumption of timely safety and economic benefits from the NAS plan may not be valid under existing conditions--judged by the current status of many projects in the plan. As mentioned earlier, our review of existing documents has shown that (1) the schedules of most major programs have slipped, (2) FAA benefits are much lower, and (3) cost estimates have risen substantially. Estimates of user benefits are currently being restudied. Also, as mentioned earlier, we believe it is not clear as to whether the NAS plan has sufficient flexibility to economically or technically accommodate satellite technology in a timely manner. Therefore,

we believe the Commission's assumption concerning the timeliness and benefits of NAS plan projects is a limitation. Consequently, we do not agree with the Commission's assumption that the NAS plan, as currently structured, should proceed without re-examination of its merits as compared to satellite system alternatives.

## FAA HAS THE OPPORTUNITY TO RECONSIDER SATELLITE TECHNOLOGY

We have reported several times over the past decade on the need to evaluate satellite technology. In a March 1978 report,[6] we called for a new direction in navigation systems planning with the advent of the Department of Defense's Global Positioning System, a satellite-based navigation system. In 1979 we reported[7] that FAA needed to increase its efforts in evaluating the use of this system for civil aviation. Further, in May 1984[8] and June 1985,[9] we suggested that there may be advantages to taking a "clean sheet" approach in evaluating the potential of alternative integrated air traffic control system architectures, including those based on satellite CNS technology.

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[6] Navigation Planning - Need for a New Direction (GAO/LCD-77-109, March 21, 1978).

[7] Should NAVSTAR Be Used For Civil Navigation? FAA Should Improve Its Efforts To Decide (GAO/LCD-79-104, April 30, 1979).

[8] Interim Observations on FAA's Plans for Major Systems Acquisitions (GAO/IMTEC-84-14, May 4, 1984).

[9] GAO Questions Key Aspects of FAA's Plans To Acquire the Multi-Billion Dollar Advanced Automation System and Related Programs (GAO/IMTEC-85-11, June 17, 1985).

It appears that the basic elements for providing enhanced satellite capabilities will soon be available. For example, the Global Positioning System is planned to provide three-dimensional coverage beginning in 1991. Another satellite service with the potential to provide navigation and surveillance capabilities may also be available by the mid-1990s. Satellite voice and data communications systems are currently available, and others will soon be available.

Although we believe the use of satellite CNS systems may satisfy more user needs, important economic, technical, and institutional questions must be answered before implementing this technology. These must be thoroughly examined before the aviation community can determine the extent to which these systems can be used to perform primarily CNS functions. For example, several potential barriers to the acceptance and implementation of satellite technology are its vulnerability to untimely notification of failure and to jamming; its cost; acquisition, development, testing, and integration questions; commercial service alternatives and attendant liability and quality assurance questions; and institutional problems of international air traffic control.

We believe that (1) substantial and immediate commitment to research, development, testing, and evaluation can overcome these problems; (2) satellite CNS systems could provide better coverage and accuracy than ground-based CNS systems; (3) satellite CNS systems could improve air traffic control over currently planned

improvements--particularly in the areas of efficiency, such as traffic management, and in safety, such as aircraft separation assurance; and (4) satellite CNS systems can improve these services as well as expand them to most of the airspace and many more airspace users.

Both the positive and negative aspects of how to apply satellite technology to air traffic control need to be considered. The Commission's study results; the advances of satellite, avionics, cockpit automation, and computer technology; and the slowdown and declining expectations in achieving the current NAS plan system modernization, create--we believe--a window of opportunity. That window of opportunity is available for Congress and FAA to take a new view of the NAS plan as a "living document" with the flexibility to evolve to meet the needs of the airspace users effectively and economically with changing technology. In that view, the plan becomes a step-by-step approach to upgrading air traffic control systems in a calculated way to take advantage of emerging technologies that potentially offer better service at a better cost.

With upcoming multi-billion dollar investment and trust fund decisions, we believe our statements today argue for an immediate and thorough re-examination of the potential use of satellite technology, including the technology's potential impact on the current NAS plan. Such a re-examination should include a full exploration of logical strategies for the transition of satellite and advanced avionics technologies to meet future air traffic

control needs. To be clear, we are not recommending either slowing down or stopping the NAS plan, but simply a thorough re-examination and some caution on the commitments to the Advanced Automation System and CNS investment commitments.

FAA has some system studies and satellite technology projects, largely unfunded, which if focused properly and actively pursued, could clarify the future role of satellite technology and how it could be integrated into the current NAS plan. However, FAA will most likely have to place a much more immediate and greater priority on research, engineering, and development efforts to solve the problems of using satellite technology effectively and economically in air traffic control. Also, based on the results of the re-examination, Congress and FAA may want to modify or reconsider a number of programs in the current NAS plan.

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That concludes my testimony Mr. Chairmar. We will be happy to answer any questions you or Members of the Subcommittee may have at this time.

Mr. BROWN. I'm going to recognize Mr. Glickman first, but before doing that, I'd just like to say that when I first initiated the process for this hearing, I had some rather vague idea in mind that we might be missing some opportunities in satellite technology, because I was aware of some of the developments, such as the global positioning system and so forth. I really had no very clear idea of the kind of window of opportunity that you're presenting here.

You've made a very good and, I consider, very strong statement which has multibillion-dollar implications, possibly even greater than that if we look at such things as global markets, global integration of aviation, and so on, and I'm very grateful to you for making this statement; I think it's very helpful to us.

Mr. Glickman.

Mr. PALMER. Thank you, sir.

Mr. GLICKMAN. Thank you, Mr. Chairman.

Just a couple of quick questions. I want to try to pin down a little bit what you are recommending. You state in your statement that you're not recommending either slowing down or stopping the NAS plan but simply a thorough reexamination and some caution on commitments to the advanced automation system and some CNS investment commitments.

Now that sounds to me like you're recommending a restructuring of the NAS plan, because you can't do one without the other. They're in the process right now of making some investment decisions on these specific items, and, in fact, if you believe that we ought to restructure the NAS plan, then I think you need to be clear about that.

Mr. PALMER. Well, the NAS plan is an agreement, if you will, with the public and the Congress and FAA as to how things are to be done for a 10-year period, implying what's to happen over a 20-year period really.

Some of the items in the promises on one side have not come through as promised, and we think it's important to reexamine that agreement, if you will.

I think decisions which would imply a wholesale commitment to the production and development of the AAS, as it's currently structured, and as I see it being designed, imply a ground-based philosophy—that is, radar data processing, flight data processing, flight plan data processing, and communications that are largely ground-based. I don't see those RE&D projects having an influence on how that design is evolving.

So I'd be very careful about making that production commitment or a fixed commitment to that system. That does not say that we sit around and wait for 3 years for those research and development projects because, frankly, when I look at the funding line on RE&D projects, those ones that we see as having the most promise in the RE&D book don't have funding until as late as 1988.

Mr. GLICKMAN. But if I may stop you, now I don't disagree with what you're saying, but you have put up some red flags on the NAS plan in your statement. You say that the plan is not going to deliver the systems and the FAA benefits expected at the cost expected or within the timeframe expected; operational problems have grown; the schedules of most major problems have slipped because of technical and management problems; FAA benefits are or

will be much lower than originally estimated; and cost estimates have risen substantially.

Now what I'm trying to get at is whether this committee and the others in Congress ought to bring the FAA in and basically say, "Stop; let's look at it," because institutionally, you know, it's pretty difficult to do what you're talking about recommending and what RTCA has indicated recommending unless Congress basically comes in and says, "OK, we want an interim period where we can really reevaluate everything we've done in the past," because your conclusions in that paragraph are pretty tough on the NAS plan. I mean, you've indicated some very grave concerns.

Mr. PALMER. I would say that we're really reporting them.

Mr. GLICKMAN. Yes, reporting them—OK—and we trust you because you don't have any axes to grind in this situation.

Mr. PALMER. I don't think we have any ax to grind on that issue, but we have reported to the Hill, and we have the report forthcoming on the slippage in the major NAS plan projects. We see in AAS, for example, which we have testified before this committee, a probable 2-year slip again in the near future. We see cost increases like about 100 percent on the DCP for the AAS. We see major cost implications there.

We understand from tracking the progress on the AERA concept, which was initially to be a package installed right around the 1990, according to the original plan, you're now seeing AERA II around the year 2000, AERA III beyond the year 2000. You're starting to get close to the 2010 point which is suggested by the RTCA.

I think that the RTCA is another factor which—their report lends credibility to this window of opportunity concept, and that is that you've got something substantive, including a statement of user needs. There may be objections and qualifiers in there, but we didn't have that kind of a statement before the NAS plan. We had it on individual areas but not as national airspace system needs.

Now while we reexamine if we grant my proposal—while we reexamine, do we stop progress? No. That would be unthinkable, in my mind. It's not a stoppage, and I don't think you're even really slowing it down if you rethink how the designs can be integrated with satellite technology. The AAS program does have quality in its contractual terms to look for extensibility to these technologies. I'm just saying, let's take a hard look at that and make sure that we're integrating it into one thinking.

Mr. GLICKMAN. Well, particularly, as you point out in your statement on page 5, it becomes more questionable whether FAA benefits expected from the NAS plan will exceed the costs.

Mr. PALMER. FAA benefits.

Mr. GLICKMAN. That's right—well, but the FAA benefits translate to the taxpayers' contribution and the users' contribution and things that are being paid by passengers, and I just want to make sure that—I don't want to slow down the situation either, because I've had a part to play early in the stage of the proposition to get this thing moving, but I also think that what you have in your statement here indicates to us that we have an obligation to maybe have a fairly short-term but intensive review of the NAS plan, particularly as it relates to some of the long-term benefits that plan was supposed to produce.

Mr. PALMER. And particularly, sir, on the end objectives of the modernization. There is a big difference between the automated decisionmaking and implied tight control over aircraft moving through the airspace, on profiles projected on the computer, as opposed to the aircraft cooperatively working with the control system and projecting itself on a fuel-efficient path, taking into account its changes for weather; its engines may not allow it to climb as rapidly as projected; and thus taking advantage of automation in the cockpit and navigational services that would be available in the cockpit. It's a different form of an end objective of your modernization, and that will take intensive reexamination, I think.

Mr. GLICKMAN. Thank you very much.

Thank you, Mr. Chairman.

Mr. BROWN. You have indicated, Mr. Palmer, on the last page of your statement, that FAA now has some system studies and satellite technology projects, but they are largely unfunded. Could you—and you further state that, if focused properly and actively pursued, they could clarify this future role of satellite technology and how it could be integrated into the current NAS plan, and I think we're deeply concerned with the integrating process, because we don't like the idea of throwing a lot of previously done work into the ashcan and then starting over again. Integration would be far preferable.

Can you give us a more specific indication of the kinds of projects that they have and the level of funding that might be required to, shall we say, provide active pursuit?

Mr. PALMER. If I may, Doug Cannon has the specific copies of the projects on this issue. But they're basically how do you take advantage of satellite technology within the system.

Mr. CANNON. Basically, we found in the current RE&D book that there are five to six projects which could, if focused properly, begin to examine more intensely the role of satellite technology in the system. There are systems studies and analysis projects which look at the entire air traffic control system architecture which are in section 2 of the RE&D. In section 8 of the RE&D book, there are three projects examining the specific satellite technology role in that overall architecture.

The first project is primarily a short-term project looking at how GPS can be integrated quickly but primarily as a navigation system. The other two—the second project is looking at satellite technology as a communications data link, and then the last project finally gets into looking at how satellite technology can influence all three of the CNS functions and fit into this systems analysis work in section 2 of the RE&D book. So those are the projects.

What we find in looking at the funding profiles is that the GPS, the short-term project, is where most of the emphasis is going. The 8.3, the third project in there, looking at the integrated approach, is actually receiving no funding that we see right now. I think it starts up in 1987-88, and in terms of levels of funding, we're talking—I think we're talking less than $1 million a year which, in total lifetime costs, we're looking at maybe $2 or $3 million into the entire project over the next several years; $2 or $3 million is a lot of money, but when compared to, I guess, some of the efforts we

see at NASA and some of the efforts at DOD, that's very small, and we're not saying, I don't think, that FAA should get in and do basic research or anything like that, it is application research, doing a lot of that with NASA and with DOD, I'm sure, to try to get a handle on the satellite technology area.

Mr. PALMER. And we can be more explicit for the record, sir.

Mr. BROWN. All right.

[The additional information follows:]

According to the FAA Plan for Research, Engineering and Development, Volume II (Draft), August 1986; the following RE&D projects are relevant to the potential integration of satellite technology into the NAS Plan:

2.1 NAS Development Studies: To develop and maintain a current plan for long-range evolution of the NAS and to derive therefrom a current R, E & D Plan (pp. 2-3 thru 2-7). Planned funding for this project is FY 86 $.531M, FY 87 .235M, FY 88 $2.483M.

2.2 Advanced Concepts Studies: To identify and explore advanced-technology concepts for providing air traffic services; these studies will be focused on the far term, when new vehicles will be operating in the NAS, and air traffic control practices may be significantly different from those in use today (pp. 2-8 thru 2-10). Planned funding for this project is FY86 $0.0M, FY 87 $0.0M, FY 88 $1.397M.

6.6 Automatic Dependent Surveillance: To develop a dependent surveillance system that will automatically provide real-time position reports of equipped aircraft within the coverage area. The initial development will be for oceanic dependent surveilllance coverage to increase airspace/air route capacity, improve traffic flow and fuel efficiency, and increase safety on transoceanic flights. The feasibility of using Automatic Dependant Surveillance to augment and improve primary radar tracking in CONUS will also be investigated (pp. 6-20 thru 6-22). Planned funding for this project is FY 86 $0.0M, FY 87 $0.280, FY 88 $4.398.

8.1 Utilization of GPS (Global Positioning Satellite) for Civil Air Navigation: to support the utilization of GPS in the NAS. GPS has the potential for providing supplemental or sole means en route navigation services, as well as nonprecision approach services, on a global basis (pp. 8-5 thru 8-7). Planned funding for this project FY 86 $2.064M, FY 87 $1.070M, FY 88 $5,146M.

8.2 Satellite-based Air/Ground Communications: To provide the information necessary for the development of satellite-based air/ground communication systems to be used for ATC voice and data transmissions (pp. 8-8 thru 8-10). Planned funding for this project is included above with Project 8.1.

8.3 Long-Range Satellite CNS Technology and Systems Applications To develop satellite-based CNS technology and systems as a function of implementation period and application. A systems approach will be used to develop a framework for the application of satellite-based CNS technologies and systems to the NAS (pp. 8-11 thru 8-13). Planned funding for this project is included above with Project 8.1.

Funding information is taken from FAA's Program Engineering & Maintenance Service: Major Programs (Smart Sheets) as of 8/01/86. Funding plans for FY 88 are subject to future budget submissions.

Mr. BROWN. Now funding for this research, of course, merely depends upon the necessary approvals within the administration to allocate these funds from the trust fund. Is that correct?

Mr. PALMER. Yes, sir.

Mr. BROWN. And, of course, because of fiscal constraints at the present time, all of this R&D which isn't immediately mandatory for the purposes of NAS is being curtailed somewhat.

Mr. PALMER. Yes, sir.

Mr. BROWN. That's a rather shortsighted view, isn't it?

Mr. PALMER. I think so, sir.

Mr. BROWN. With regard to the implications of this for other agencies—NASA and DOD you've mentioned—is it likely that there might be some need to expand or redirect some of their research programs if it should become obvious that we're better off to focus on these satellite-based systems in order to achieve economies in our total airspace plan?

Mr. PALMER. I think that would be very apropos, and thinking as a government as a whole and to whom—its savings to the taxpayers as a whole—rather than just individual missions of the agencies. FAA has relied on the agencies of DOD and NASA in the past for some basic R&D work, and we would expect that they would rely on them for, certainly, much of their satellite technology and launching expertise. Other institutions like JPL could be very valuable, and they, of course, have MITRE on tap. Rand, I don't think, has been much involved even though they had some very interesting views in the early 1980's.

Mr. BROWN. Actually, I have a vague recollection that there are being explored now a number of other applications for satellite technology for similar purposes involving control of ground-based systems of various kinds, such as railroad car movements, truck movements, various things. Is it conceivable that a total satellite system might have broader applications than merely to the airspace community?

Mr. PALMER. I firmly believe that Geostar believes that as well as other people that are considering commercial ventures like that—with their radio determination satellite service. Those applications are viable.

Mr. BROWN. Looking at our total national posture in advanced technology, we might be missing some opportunities here to establish global leadership in applications that would be useful to our further economic development.

Mr. PALMER. I think so.

Mr. BROWN. These, of course, are the kinds of things that we think about all the time in this committee, and we don't like to miss an opportunity to focus on it a little bit.

Mr. PALMER. Well, I think that, you know, they're reasonable projections of what is or will become available, and the broader the implementation or user base for those technologies, the more cost effective they become and usually the better they become.

Mr. BROWN. Yes. Of course it's disturbing to us here in the committee to see, because of our neglect to aggressively pursue some of these things, that other nations are carving out niches in which they are moving ahead more rapidly than we are and usurping a

lot of significant markets that we haven't bothered to examine as carefully as we should.

Mr. Packard, I know that you got here a little late—I'm not criticizing you. You had a very important reason for it. Do you have any questions at this point?

Mr. PACKARD. Well, we did have an important markup in another committee, and I apologize for not being here, and I really don't have questions. I'm sorry that I've missed this very interesting hearing—most of it.

Mr. BROWN. All right.

Thank you very much, Mr. Palmer.

Mr. PALMER. Thank you, sir.

Mr. BROWN. It's been extremely interesting testimony.

Our next witness is Mr. Roy Anderson, chairman of the Satellite Service Providers Group and advisers to the U.S. Member of the Future Air Navigation Systems Committee, International Civil Aviation Organization.

Mr. Anderson, you know I'm an amateur in this field, so you can sort of give me a little background as you go along on all these activities.

**STATEMENT OF ROY E. ANDERSON, CHAIRMAN, SATELLITE SERVICE PROVIDERS GROUP, ADVISERS TO THE U.S. MEMBER OF THE FUTURE AIR NAVIGATION SYSTEMS COMMITTEE, INTERNATIONAL CIVIL AVIATION ORGANIZATION, ACCOMPANIED BY JAN KING, VICE PRESIDENT OF ENGINEERING, SKYLINK CORP.**

Mr. ANDERSON. Mr. Chairman, I am Roy Anderson, chairman of the Satellite Service Providers Group, a committee organized at the request of the FAA Administrator to advise the U.S. Member of the Future Air Navigation Systems Committee of the International Civil Aviation Organization. I am also the vice present of Mobile Satellite Corp., the first commercial enterprise that applied to the Federal Communications Commission for authority to provide aeronautical and other mobile satellite services to the United States.

With me is Mr. Jan King, vice president of engineering, Skylink Corp. He is a prominent member of the Providers Group. Skylink is another pioneer applicant for authority to provide the service.

The Providers Group includes several others of the 12 companies whose competing applications are on file at the Federal Communications Commission. It also includes Comsat, the U.S. signatory of Inmarsat, which plans to provide aeronautical services on a worldwide basis. Avionics equipment manufacturers also participate, and while my testimony this morning has not been reviewed formally by the Satellite Service Providers Group, I do believe that it represents a consensus of their views.

The FAA has stated that the Aeronautical Mobile Satellite Services (R) which pertain to the safety and regularity of flight can be provided by commercial entities and that the satellites and frequency bands can be shared with other nonsafety aviation and other services if instantaneous access, protection from interference, and priority are guaranteed for those AMSS(R) services. The Service Providers agree with those criteria.

I mentioned AMSS(R). That stands for Aeronautical Mobile Satellite Services, (R), which pertain only to the safety and regularity of flight. They are air traffic control and airlines operational control; they do not include other aviation uses such as passenger telephone.

The FAA recognizes that satellite and spectrum sharing could be beneficial to aviation because of the possibility of sharing the high cost of space segment resources. The airlines also recognize the economic value of sharing. They are planning to use the satellites, avionics, and bands for passenger telephone, telex, and airline administrative communications as well as AMSS(R) services.

The provision of the services by commercial entities rather than by the Government will have other benefits. Competitive pressures will result in the earliest possible operational service and affordable costs. Growth in service demand will impose strong incentives to implement technologies that maximize system capacity and performance. Investment and financial risk will be in the private sector. The taxpayers' money is not involved in the financing of the space-based portion of the system.

Commercial entities can provide the services, however, only if the total market they serve is large enough to justify the investment. In order to ensure an adequate market, space communication resources must be shared with nonaviation services. The FCC recognized that fact recently when it allocated the L-band to a variety of aeronautical, land, and waterway mobile satellite services in the United States.

Sharing the band with nonsafety and nonaviation services imposes some regulatory and technical requirements to ensure the availability, integrity, and capacity growth of the AMSS(R) services. A regulation must establish the right, in perpetuity, of sufficient band width in the L-band to serve aviation's satellite communication, navigation, and surveillance needs. Service providers must fulfill those needs, but aviation must forewarn the service providers of any increase in need that will require additional facilities.

Technical requirements imposed by sharing include specifications of equipment design and operational procedures that apply to services other than AMSS(R). Suggested approaches include the use of a continuous down-link control channel. The user transmitter will be blocked from transmitting if it is not receiving the control channel.

An additional system feature is a network control center that continuously monitors all nonaviation users of the band and immediately turns off via the control channel any unit that is off frequency or transmitting spurious radiation.

The AMSS(R) will be assigned an exclusive portion of the band. Aeronautical safety will be separated in frequency from other services so that the probability of significant interference is negligible.

Now having identified some principles by which the satellites and spectrum can be shared, we turn to the specifics of the aeronautical satellite (R) service plans and implementation.

A word of caution is necessary here. Satellites will provide new and improved services to aviation, but they are not a replacement for existing communication and navigation systems. While they

must be taken into account in the national airspace plan, they do not cause that plan to become obsolete. Satellites will augment the plan by serving areas below line-of-sight coverage from ground-based VHF and radar. An example is rotocraft operating offshore or in remote mountainous areas.

Satellites will serve airspace where flight is restricted due to limited air traffic control capabilities and may serve landing areas that do not have terminal landing aids.

Satellites will fulfill many unmet requirements worldwide, especially in oceanic and sparsely populated regions of the world.

The initial AMSS(R) requirements are automatic dependent surveillance and digital communications between aircraft and air traffic service units. I think automatic dependent surveillance has been defined by several of the people before. It is the automatic transmission of position fixes determined by onboard navigation aids. GPS is a good candidate for one of those aids.

A two-way communication channel at 300 information bits per second could serve up to 200 aircraft. Additional channels are added as required to meet the needs of all aircraft served by a satellite. That core AMSS(R) capability must serve all types of aircraft, including general aviation aircraft, with 0 dBi nonsteerable antennas, nondirectional antennas. An emergency voice channel may be available to aircraft with 0 dBi antennas through spot beam regional satellites such as those to be implemented by service providers in the United States.

The world will be served by some global satellites that cover large regions of the earth over the oceans, and over the United States, for example, by a regional satellite with much higher capacity.

Larger aircraft will use the core capability and also an expanded capability that may include several simultaneous voice transmissions for airline administrative communications and passenger telephone or digital communications. The expanded capability will be available through global beam satellites to aircraft with higher gain antennas such as 12 dBi steerable antennas.

Present spacecraft and avionics technology can provide the initial core capability for all aircraft and the expansion capability for aircraft with higher gain antennas. The system architecture and structure developed by the FANS working group, with the assistance of the service providers, will fully meet the initial requirements. The capability for growth is inherent in the system structure.

System capacity will grow through frequency and orbit reuse. Satellites with large antennas form many spot beams on the regions they serve. Each channel can be used in a number of the beams, thus multiplying the number of users that can be served by each satellite. Further multiplication can be done by increasing the number of satellites, spacing them more closely in orbit. Spacing can be reduced if the mobile antennas have narrow beams that are automatically steered toward only one of the satellites, thus avoiding interference to the other satellites.

While the first systems may have some frequency and orbital reuse by these techniques, there is much that can be done to im-

prove them. NASA should be encouraged in its development of large satellite antennas.

Steerable aircraft antennas are a challenge, but useful designs are available. Present electronically steered antennas have keyholes of degraded performance in their patterns fore and aft because they must be mounted on the sides of the aircraft. Mechanically steered antennas do not have keyholes, but they require protruding radomes that have unacceptable drag on some aircraft.

Continued work on mobile antennas, both electronically and mechanically steered, will lead to lower cost and better performance. Some research is needed in that area, particularly to advance the directional antennas for use on general aviation aircraft.

Efficient use of the spectrum is extremely important. Modulation, access, and coding choices affect spectrum efficiency. The choices made for the initial systems are highly efficient for the data rates and the expansion capabilities. As demand increases, other techniques may be chosen as a part of the system's evolutionary development.

Digital transmission of speech is the present choice of the aviation community because it is compatible with the digital data transmission. Digitally processed speech transmitted in minimum band width is poorer in quality than analog speech in the same band width. Further work in digital speech processing is expected to improve quality.

Avionics equipment that can transmit digital data and analog voice should be investigated as an alternative to the use of digitally processed speech.

Signals transmitted between the aircraft and satellites experience doppler shift. Efficient use of the spectrum requires that the doppler shift be measured on the signal received in the aircraft and compensated on the path from the aircraft to the satellite. The measurement and compensation require a reference oscillator in the aircraft that is accurate to one part in 10 million. Suitable oscillators are available, but lower-cost oscillators are needed for general aviation.

Cooperative independent surveillance can be achieved by using the communication channels to measure the ranges from two or more satellites to the aircraft. Three satellites are needed if altitude is to be determined, and at least one of the three must not be in geostationary orbit.

While cooperative independent surveillance techniques may have some limited application in the early implementation, its use will not be widespread unless inclined orbit satellites become available. Inclined orbit satellites could provide communications in the polar regions.

There are some other issues with regard to cooperative independent surveillance that I think need review as well. However, it does have some promise.

Automatic dependent surveillance will be used in the near term. The use of inclined orbit satellites for cooperative independent surveillance and polar coverage should be determined by comparing the performance of the two methods of surveillance, the value of polar coverage, and the cost of adding inclined orbit satellites to the system.

It has been suggested that some direct air-to-ground ATC communications should be done in the L-band so that a single avionics unit in the aircraft can be used for satellite and direct air-ground communications. While the objective may have merit, the service providers believe that the approach is unwise.

Everyone agrees that the spectrum available for satellite communications is limited. It should not be diverted for purposes that are better served with existing facilities.

VHF cannot be phased out in the foreseeable future, and therefore aircraft will continue to carry VHF equipment. A different approach to the objective should be considered. An avionics unit with the satellite signaling characteristics might be designed with L-band and VHF capability.

The Federal Aviation Administration has based its policy on the recognition that there are substantial economic and other benefits if the aeronautical satellite (R) services are obtained from commercial providers. Like others in the aviation community, it also perceives some risks in allowing non-aviation services to share the satellite facilities.

The FAA has wisely involved the service providers in the development of the system architecture and engineering design of the system. Aviation benefits from the FAA initiatives by assuring that the providers have the information necessary to build a system that is cost effective and that fulfills the needs without risk to the availability and integrity of the safety services.

As you heard this morning, the aviation community is working diligently to define the aeronautical satellite system and its operation. Commercial entities in the United States are competing for the opportunity to provide the service. The Federal Communications Commission has made a frequency allocation that will make the service economically viable.

There is international interest in an effort to establish the service worldwide. The 1987 World Administrative Radio Conference will decide the international allocations for mobile satellite services. Not all of these efforts are in concert.

The U.S. Government can expedite the process of establishing the service if it will take the following actions: One, register strong support for the FCC allocation of the L-band to the Mobile Satellite Service at the 1987 Mobile WARC; two, prepare a regulation that assures priority access for safety services; three, establish a means to insure coordination with other administrations for the use of the L-band including that portion that is allocated to Mobile Satellite Service on a secondary basis; four, foster Canadian support for the L-band allocation by prompt allocation of UHF reserve spectrum to the Mobile Satellite Service; and five, expedite the rulemaking and licensing of the Mobile Satellite Service.

Thank you for this opportunity to present the views of the Satellite Service Providers Group to the commission.

[The prepared statement of Mr. Anderson follows:]

Testimony of

Roy E. Anderson, Chairman
Satellite Service Providers Group
advisors to
The U.S. Member of the Future Air Navigation Systems Committee
International Civil Aviation Organization

before the

Subcommittee on Transportation,
Aviation and Materials

United States House of Representatives
Committee on Science and Technology

September 24, 1986

Mr. Chairman, I am Roy E. Anderson, Chairman of the Satellite Service Providers Group, a Committee organized at the request of the FAA Administrator to advise the U. S. Member of the Future Air Navigation Systems (FANS) Committee of the International Civil Aviation Organization (ICAO).

I am involved in several other aspects of the planning and implementation of the service. As the Vice President of Mobile Satellite Corporation, (MOBILESAT[sm]), I have a vital interest in the prompt and economically viable implementation of the service. Our company was the first commercial enterprise that applied to the Federal Communications Commission for authority to provide aeronautical and other mobile satellite services to the United States.

With me is Mr. Jan King, Vice President of Engineering, Skylink Corporation. He is a prominent member of the Providers Group. Skylink is another pioneer applicant for authority to provide the service.

The Providers Group includes several others of the twelve companies whose competing applications are on file at the Federal Communications Commission. It also includes COMSAT, the U.S. signatory of INMARSAT, which plans to provide aeronautical services on a worldwide basis. Avionics equipment manufacturers also participate.(1) The Group works very closely with the FAA, with entities that currently provide communications to the airlines, and representatives of general aviation. While my testimony has not been reviewed formally by the Satellite Service Providers Group, I believe that it represents a consensus of their views.

The FAA has stated that the aeronautical mobile satellite (R) services, which pertain to the safety and regularity of flight, can be provided by commercial entities and that the satellites and frequency bands can be shared with other services if instantaneous access, protection from interference and priority are guaranteed for those AMSS(R) services. The Service Providers agree with those criteria.

The Service Providers that I represent today are the commercial entities that offer to provide those services.

The FAA recognizes that satellite and spectrum sharing could be beneficial to aviation because of the possibility of sharing the high cost of space segment resources. The airlines also recognize the economic value of sharing. They are planning to use the satellites, avionics, and bands for passenger telephone, telex, and airline administrative communications as well as AMSS(R) services.

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(1) A list of the participants and observers is attached.

The Service Providers agree that sharing the space segment resources and the frequency bands will be beneficial economically, and we believe that the provision of the services by commercial entities rather than by the government will have other benefits as well. Competitive pressures will result in the earliest possible operational service and affordable costs. Growth in service demand will impose strong incentives to implement technologies that maximize system capacity and performance. Investment and financial risk wil be in the private sector. The taxpayers are not involved in the financing of the system.

Service Providers have an incentive to participate only if the total market they serve is large enough to justify the investment. In order to assure an adequate market, space communication resources must be shared with non-aviation services. The FCC recognized that fact recently when it allocated the L-band to a variety of aeronautical, land and waterway mobile satellite services in the United States. Those services include mobile radio telephone for non-urban residents who have no prospect of cellular radio telephone service, digital and voice communications for transportation industries, wide area and remote area communications for state and nationwide public safety, health services, law enforcement, search and rescue, disaster control, and many other important applications. The satellites will be the dominant, if not the only service to rural America.

Services to the variety of users results in an economy of scale that reduces costs to all, including aviation. The research and development effort for the shared services will benefit aviation.

Sharing the band with non-safety aviation services imposes some regulatory and technical requirements to insure the availability, integrity and capacity growth of AMSS(R) services.

A regulation must establish the right, in perpetuity, of sufficient bandwidth in the L-band[2] to serve aviation's satellite communication, navigation and surveillance needs for the safety and regularity of flight. Service Providers must fulfill those needs, but aviation must forewarn the service providers of any increase in need that requires additional facilities in sufficient time to provide the facilities.

Technical requirements imposed by sharing include specifications of equipment design and operational procedures for services other than AMSS(R). Suggested approaches include the use ofa continuous downlink control channel that serves as a frequency reference for channel assignment and steerable antenna

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(2) The present international allocation of the aeronautical L-band is 1545-1559 MHz space to earth, and 1646.5-1660.5 MHz earth to space.

pointing. The user transmitter will be blocked from transmitting whenever the control channel is not received. An additional system feature is a network control center that continously monitors all non-aviation uses of the band and immediately turns off, via the control channel, any unit that is off-frequency or transmitting spurious radiation.

AMSS(R) will be assigned an exclusive portion of the band. Aeronautical safety and other services will be separated in frequency and the probability of significant interference is negligible.

The network control center will have the capability of assigning users on a demand assigned multiple access basis. Service to any non-aviation (R) user can then be refused, reassigned to another channel, or terminated instantaneously. The dynamic control enables the amount of capacity available to aviation safety to match requirements at all times even if the demand exceeds the capacity of the portion of the band that is exclusively assigned to the service.

Having identified some principles by which the satellites and spectrum can be shared, we now turn to the specifics of the aeronautical satellite (R) service plans and implementation.

A word of caution is necessary here. Satellites will provide new and improved services to aviation, but they are not a replacement for existing communications and navigation systems. While they must be taken into account in the National Airspace Plan (NASP) they do not cause that plan to become obsolete. Satellites will augment the plan for areas below line-of-sight coverage from ground based VHF and radar. An example is rotocraft operating offshore or in remote and mountainous areas. Satellites will serve landing areas which do not have terminal landing aids and other airspace where flight is restricted due to limited Air Traffic Control (ATC) capabilities.

Satellites will fulfill unmet requirements worldwide, especially in oceanic and sparsely populated regions of the world.

Initial requirements for air traffic control (ATC) and airlines operational control (AOC) are automatic dependent surveillance and digital communications between aircraft and air traffic service units. A two-way communication channel at 300 information bits per second could serve up to 200 aircraft. Additional channels are added as required to meet the needs of all aircraft served by a satellite.

That "core" capability must serve all types of aircraft, including general aviation aircraft with 0 dBi non-directional antennas.

Larger aircraft will use the core capability, and also an expanded capability that may include several simultaneous voice

transmissions for airline administrative communications and passenger telephone or digital communications. The expanded capability will be available through global beam satellites to aircraft with higher gain, such as 12 dBi, steerable antennas. An emergency voice channel may be available to aircraft with 0 dBi antennas through spot beam regional satellites, such as those to be implemented by service providers in the United States.

Aviation services, AMSS(R) and the expanded service, must be in the L-band because they will be implemented according to international standards and the avionics equipment cannot be changed. The core capability and the expanded capabilities can be provided with integrated avionics. The growing needs of aviation must then be met within that band. Non-aviation services could be expanded into other bands if they become available. Total capacity within the L-band will increase with demand thorugh the use of multi-beam satellites, increased number of mobile satellites and other means to reuse frequencies and conserve bandwidth.

Present spacecraft and avionics technology is sufficient for the initial core capability and the expansion capability for aircraft with higher gain antennas. The system architecture and structure developed by the FANS working group, with the assistance of the Service Providers, will fully meet the initial requirements. The capability for growth is inherent in the system structure.

Future spacecraft and avionics technology will expand total system capacity and add new services. The future developments must not obsolete older avionics equipment or the availablity of the basic services.

System capacity will be expanded by freqency and orbit reuse. Satellites with large antennas form many spot beams on the regions they serve. Each channel can be used in a number of the beams, thus multiplying the number of users that is served by a satellite. The number of satellites can be increased by spacing them more closely in orbit. Spacing can be reduced by the use of mobile antennas that have narrow beams that direct their signals toward only one of the satellites. The antennas keep pointing at the satellite as the vehicle turns, climbs, or banks. While the first systems will have some frequency reuse by these techniques there is much that can be done to improve them. NASA should be encouraged in its development of the large satellite antennas.

Steerable aircraft antennas are a challenge. Present electronically steered antennas have "keyholes" in their patterns fore and aft because they must be located on the sides of the aircraft. Closer spacing of satellites can compensate for the keyholes by assuring that there is always a satellite in a favorable direction relative to the flight path. Mechanically steered antennas do not have keyholes but require protruding radomes that have unacceptable drag on some jet aircraft.

Continued work on mobile antennas, both electronically and mechanically steered, will lead to lower cost and superior performance.

Efficient use of the spectrum is extremely important. Modulation, access and coding choices affect spectrum efficiency. The choices made for the initial system are highly efficient for the data rates of the core and expansion capabilities. As demand increases, other choices may be made as a part of the system's evolutionary development. Digital transmission of speech is the present choice of the aviation community because it is compatible with the digital data transmission. Digitally processed speech transmitted in minimum bandwidth is poorer in quality than analog speech in the same bandwidth. Further work in digital speech processing may improve quality. Avionics equipment that can transmit digital data and analog voice may become a feasible alternative to the use of digitally processed speech.

Signals transmitted between the aircraft and satellites experience doppler shift. Efficient use of the spectrum requires that the doppler shift be measured on the signal received in the aircraft and compensated on the path from the aircraft to the satellite. The measurement and compensation require a reference oscillator in the aircraft that is accurate to one part in ten million. Suitable oscillators are available, but lower cost oscillators are needed to serve the needs of general aviation.

Cooperative independent surveillance can be achieved by using the communication signals to measure the ranges from two or more satellites to the aircraft. Three satellites are needed if altitude is to be determined, and at least one of the three must not be in geostationary orbit. While cooperative independent surveillance may have some limited application in the early implementation, its widespread use may come when non-geostationary satellites are available to provide polar coverage. Surveillance in the near term will be achieved with automatic dependent surveillance.

It has been suggested that some air-to-ground ATC communications be done in the L-band so that a single avionics unit in the aircraft can be used for satellite and direct air-ground communication. While the objective may have merit, the service providers believe the approach is unwise. Everyone agrees that the spectrum available for satellite communications is limited. It should not be diverted for purposes that are better served with existing facilities. VHF cannot be phased out in the foreseeable future, and therefore aircraft will continue to carry VHF equipment. A different approach to the objective might be considered. L-band- to - VHF frequency conversion circuits could be added to the satellite avionics so that the unit could be switched to VHF for direct air ground communication, introducing the bandwidth efficient digital communications into the VHF band.

The Federal Aviation Administration has based its policy on

the recognition that there are substantial economic and other benefits if the aeronautical satellite (R) services are obtained from commercial providers. Like others in the aviation community it also perceives some risks in allowing non-aviation services to share the satellite facilities. The FAA has wisely involved the service providers in the development of the system architecture and engineering design of the system. Aviation benefits from the FAA initiatives by assuring that the service providers have the information necessary to build a system that is cost effective and that fulfills the needs without risk to the availability and integrity of the safety services.

The nation as a whole benefits from the FAA recognition that the satellites and bands can be shared with non-aviation services provided that adequate capacity is always available for aviation safety services.

The aviation community is working diligently to define the aeronautical satellite system and its operation. Commercial entities in the United States are competing for the opportunity to provide the service. The Federal Communications Commission has made a frequency allocation that will make the service economically viable. There is international interest and effort to establish the service worldwide. The 1987 Mobile World Adminstrative Radio Conference (WARC) will decide the international allocations for mobile satellite services. Not all of the efforts are in concert. The U.S. Government can expedite the process of establishing the service if it will take the following actions:

- Register strong support for the FCC allocation of the L-band to the mobile satellite service at the 1987 Mobile WARC.
- Prepare a regulation that assures priority access for safety services.
- Establish a means to insure coordination with other administrations for the use of the L-band including that portion that is allocated to Mobile Satellite Service on a secondary basis.
- Foster Canadian support for the L-band allocation by prompt alloction of the 849-851/894-896 MHz band to the Mobile Satellite Service
- Expedite the rulemaking and licensing of the Mobile Satellite Service.

Thank you for this opportunity to present the views of the Satellite Service Providers Group to the Committee.

Mr. BROWN. Thank you very much, Mr. Anderson.

Mr. Packard, do you have any questions?

Mr. PACKARD. What are the estimated costs for general aviation to implement the system, that would put them on to the system?

Mr. ANDERSON. Do you mean to provide the avionics units in the aircraft of general aviation?

Mr. PACKARD. Yes.

Mr. ANDERSON. Well, the present core system avionics are being considered by the airlines' Electronic Engineering Committee, which seems to emphasize the airline applications. It's hard for me to give you a cost estimate of that equipment now.

With the 0 dBi antennas on the aircraft for the core capability, I think it will be within the cost limits of most general aviation aircraft.

Mr. PACKARD. Do you think that the marketplace will be driven or will drive the program, or do you think that the Government will have to be the primary source of emphasis?

Mr. ANDERSON. If you give the entrepreneurs in the United States the chance, they certainly are eager and ready to provide the space facilities, satellites in orbit, for this purpose; they are eager to do so, they want to do so, and they are ready to go.

Mr. PACKARD. How long do you think it would take for the technology to be ready in the various service areas?

Mr. ANDERSON. The technologies are ready now for the core system. The advanced technologies for further expansion and growth to higher capacity systems is something that should be investigated. So it is ready to go, and the market is driven by the shared use of the band. The core demand at the present time would require a very small part of the spectrum. It will grow, of course, with the future. But the shared use of the band can drive the implementation of this system forward very promptly.

Mr. PACKARD. So you don't see any further research necessary to permit the aircraft to operate in the space-based TC system?

Mr. ANDERSON. Not for the initial core system, but for its evolution there should be further developments, because the capacity will have to grow with demand.

There is one other aspect of this. The regional systems for the United States, for example, must serve a very high density of users. The global regions over the oceans that serve a low capacity, those systems must be integrated so that an aircraft equipped to fly in one area can transition to another area and still get the service.

Jan, would you care to comment on that?

Mr. KING. I think in the work that we've been doing in the service providers' portion of the future navigation system work in the United States, we have particularly tried to focus on the issues of global interoperability and upward compatibility, and I think it's safe to say that the work that's going forward which has been largely prepared by the U.S. group, that has been accepted now in preparation for the FANS meeting in November, represents a system that we all agree upon and is a system which does consider carefully the international entry into an overall aeronautical mobile satellite system and addresses the issues of the possibility of even changing the architecture at a later time to accommodate

more sophisticated scenarios. So I think we've very definitely looked at that in detail.

Mr. PACKARD. Do you see a time when this will become mandatory equipment on an aircraft, or will it remain optional?

Mr. ANDERSON. I don't pretend to be an authority on air traffic control. I think that for any aircraft that flies under instrument flight rules would have to be equipped eventually for this.

Mr. PACKARD. Thank you, Mr. Chairman. I have no further questions.

Mr. BROWN. You have mentioned that the present state of technology will allow for the initial deployment of the system here, but we might require additional R&D in the future. This committee has been grappling with the funding of the advanced communications technology satellite program in NASA. Is the thrust of that research such as to provide the kind of technology that would be required for future use here?

Mr. ANDERSON. I believe so. Where I think some of these research and development funds should be are in advanced space technologies, such as large spacecraft antennas. The thing we'd all like to see also is a means to have higher power satellites.

Mr. BROWN. That, as I understand it, is at least in part the focus of the act's program, but it also includes beam focusing and multiple use of beams.

Mr. ANDERSON. That is correct. We need for the future to serve the regional areas such as the United States satellites with many beams, perhaps 40- to 100-beam satellites in the future, to give us a nationwide cellular system, if you will, in which we can have substantial reuse of the spectrum in order to get the traffic up. The means to transition from beam to beam, of course, is known, but the techniques and procedures for that are important.

The aircraft antenna designs is another area, to get the costs of those down and their performance up. Particularly the cost is quite high right now.

We need spectrum efficient technologies and modulation coding and access techniques. We need more work on digital speech transmission, and we should also look at the integration, broader integration, of the services in the aircraft avionics equipment.

Mr. BROWN. You have, in your statement, included some reference to most of these things, but if you could supply for the record additional justification or description of these things, it would be helpful for the record, because this committee is interested in furthering the R&D and the technology—development technology base, and you give us a menu, and we'll probably bite on it.

Mr. ANDERSON. Very good. We appreciate that.

[The information follows:]

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October 2, 1986

The Honorable George E. Brown,
Chairman, Subcommittee on
Transportation, Aviation and Materials,
Committee on Science and Technology
U. S. House of Representatives
Suite 2321 Rayburn House Office Building
Washington, DC 20515-6301

Dear Congressman Brown,

In response to your request, I am suggesting a list of Aeronautical Mobile Satellite (R) developments and investigations that should be supported by the Government. Technologies are in hand for the "core" capability and there should be no delay in proceeding with its implementation. The core capability has a flexible design that will not become obsolete as the system grows and other functions are added. The items in the following list are needed for optimization and growth.

1. Multibeam satellite antennas 20 meters in diameter and larger.

Satellites with many beam footprints are needed for frequency reuse in order to satisfy the large future demand for service. Mechanical aspects of the antenna include unfurling the aperture and multiple feed configuration in space, confirmation of integrity by ground test or other means and achieving a light weight sturdy configuration suitable for a commercial, high performance, long lived, insurable satellite. A large antenna affects the design of other parts of the spacecraft, and introduces new considerations on launch and deployment. The development should proceed without delay. Multibeam satellites may be needed as early as 1997 for the United States.

2. Steerable aircraft antennas.

Aircraft antennas with directional beams are needed for voice and high data rate digital communications. The directional beams enable closer spacing of satellites in orbit, greater communication capacity, reduced service costs and reduced inter-system interference. Antenna gain in the range of 9-14 dBi is required. In the future even higher antenna gains may be needed. The antennas must have low drag, hemispherical coverage, minimum complexity for installation and maintenance. Acceptable antennas are available for the initial system for use on airline aircraft,

but they are deficient in coverage and costly. Improved designs are desired for airline use, and low cost versions are needed for general aviation.

Related work is in progress in support of the land mobile satellite service. One center of activity is the Jet Propulsion Laboratory.

3. Spectrum efficient modulation, coding and access techniques.

Modulation techniques need further investigation to optimize signal bandwidth and interference.

Low data rate digital speech transmission is intelligible but of poor quality. Improvement is needed.

The development of a modem that will accommodate narrow band analog voice transmission and digital data transmission could provide good quality voice transmission and efficient digital data transmission.

The successful development of the two items above will provide choices for optimization.

Coding techniques need further investigation to optimize message transmission time and message integrity.

While single channel per carrier - frequency division multiple access is recommended for the "core" capability, other access techniques should be considered for functions that require high communication data rates and precise resolution of signal propagation time.

4. Inclined orbit or polar orbit satellites

Orbit designs and economic value of non-equatorial satellites should be investigated.

Geostationary satellites, in the plane of the equator and moving eastward at an altitude of 22,300 miles, appear stationary with respect to the earth's surface. They are useful between the latitudes of about 70 degrees north and south, and are preferred for communications in that service area because the ground stations do not have to have tracking antennas and there are no interruptions in service. Communications in the polar regions require satellites in orbits inclined to the equator so that the satellites move north and south of the equatorial plane.

Cooperative independent surveillance by ranging from geostationary satellites can determine aircraft latitude and longitude at mid latitudes, and longitude near the equator. Inclined or polar orbiting satellites must be included in the constellation if altitude of the aircraft must be determined and if service is needed near the equator.

The inclined or polar orbiting satellites can be of any altitude, but the number and cost of the satellites is a function of their altitude. They must be tracked by the ground earth station antennas, adding cost and complexity to the ground earth stations.

The inclined or polar orbiting satellites can add to the total communications capacity of the systems as well as provide the polar coverage and cooperative independent surveillance.

5. Avionics equipment

Avionics equipment for the initial core capability must have the flexibility to accommodate additional functions as they become available. The Airlines Electronic Engineering Committee is considering a modular design that will serve the needs of airline aircraft. Avionics packaging for general aviation aircraft needs further consideration.

State of the art technology will be applied by avionics equipment manufacturers without government support. Government supported research can advance the state-of-the art and lead to substantial improvements in the future.

Improved efficiency of L-band radio frequency power amplifiers could increase the number of simultaneous communication channels that can be transmitted from an aircraft and mitigate the serious problem of heat dissipation in the avionics.

Stable reference frequency oscillators and methods of doppler compensation need further investigation. Low cost methods of achieving the compensation are important to general aviation.

Common avionics for compatible terrestrial and satellite communications is an important goal. It can substantially decrease the equipment load on aircraft and simplify cockpit workload. One suggestion is to incorporate the satellite communications signalling in the terrestrial systems. The radio transmissions can then be at VHF or at L-band when communicating terrestrially. (The satellite Service Providers are opposed to terrestrial communications in the L-band.)

6. Worldwide standardization

Satellite services will be provided by a variety of systems worldwide. Some will be high capacity multibeam regional systems such as in the United States. Others will be lower capacity global beam systems serving low population density or oceanic areas. An aircraft must be able to fly anywhere in the world and obtain service with one set of onboard avionics.

Self contained Air Traffic Service ground stations must be developed for use in remote areas.

Operational procedures must be defined for transitions between low density and high density areas.

7. Technologies for incorporating mobile satellite communications into the National Airspace Plan

The functions best served by satellite within U.S. airspace must be identified and the requirements quantified. Past

consideration for aeronautical satellite communications has concentrated on oceanic service.

Methods of traffic handover between terrestrial and satellite systems and between beams in a multibeam satellite system must be defined.

Methods of integrating the terrestrial and satellite signaling characteristics and message handling must be developed.

Priority access and protection of safety services must be assured.

Thank you for the opportunity to make these suggestions to your Committee. I will be pleased to discuss them further with you or your staff.

Sincerely,

Roy E. Anderson

Roy E. Anderson, Chairman,
Satellite Service Providers
Working Group

REA/ga

Mr. BROWN. Now with reference to the satellites themselves, you were describing mostly geostationary communication satellite deployment here, but for purposes of positioning you indicated the need for midorbit——

Mr. ANDERSON. Inclined orbit satellites.

Mr. BROWN. Inclined orbit. These would be in the orbits around 11,000 miles or something like that.

Mr. ANDERSON. Well, they could be in geosynchronous orbit.

Mr. BROWN. They could.

Mr. ANDERSON. The altitude isn't as important as the fact that they must move north and south of the Equator.

Geostationary satellites in the equatorial plane are in a straight line virtually, and they do not provide position location near the Equator, only lines of position. They do not see the poles, and if you get—they can't measure altitude.

Mr. BROWN. I understand that. I'm unfamiliar with any satellites at geostationary orbits on polar orbit.

Mr. ANDERSON. Well, geostationary means they are in the equatorial orbit.

Mr. BROWN. I mean geostationary distances but in polar orbits.

Mr. ANDERSON. Well, they are not normally placed there, although some of the satellites that have been orbited in eccentric orbits or elliptical orbits do go north and south and exceed the geostationary height.

Mr. BROWN. Yes.

Mr. ANDERSON. So that's not the issue, the actual altitude.

Mr. BROWN. No, it doesn't make much difference what the altitude is, does it?

Mr. ANDERSON. That's correct, except that it may affect the number of satellites that you need in order to do it.

Mr. BROWN. Yes.

Could you provide any information on, I guess you would call it the system architecture to provide that sort of coverage that you're talking about?

Mr. ANDERSON. For the polar orbit coverage?

Mr. BROWN. Yes.

Mr. ANDERSON. That has not been addressed in detail. I should say that at this time the service providers that I represent are not greatly interested in placing satellites in any orbits except the equatorial geostationary orbits so that in order to provide that facility another initiative may have to be taken there. However, that view may change. The reason is that we like to be able to communicate from the ground to a satellite that has a fixed point in space rather than having to try to track it.

Mr. BROWN. Right.

Mr. ANDERSON. That's why I mentioned that cost is a thing that needs to be considered in evaluating polar coverage.

Mr. BROWN. Do you have any further questions?

Mr. PACKARD. I don't, Mr. Chairman.

Mr. BROWN. I can envision a lot of questions I'd like to ask you, but because I am relatively unsophisticated in this area I'm not going to struggle through it. I may want to ask you some questions in writing, if I may.

Mr. ANDNERSON. We'll do our best to give you answers.

Mr. BROWN. Thank you very much, and we'll excuse you at this time then.

Our last witness this morning is Mr. Siegbert Poritzky, director, System Studies and Cooperative Programs, with FAA.

**STATEMENT OF SIEGBERT PORITZKY, DIRECTOR, SYSTEM STUDIES AND COOPERATIVE PROGRAMS, FEDERAL AVIATION ADMINISTRATION, ACCOMPANIED BY LEE PAGE, DIRECTOR, SYSTEM ENGINEERING**

Mr. PORITZKY. Thank you, Mr. Chairman, members of the subcommittee.

To my right is Mr. Lee Page, who is the FAA director of System Engineering. There are also sitting, in back of us, several of the real experts in this area.

We welcome the opportunity to review for you FAA's involvement in satellite technology. It's nearly 30 years after the launch of the first satellite and nearly 25 years that FAA became active in the study of satellite applications.

The great potential of satellite services to civil aviation, we believe, may soon be realized. We are close to achieving international agreement on a satellite communications architecture, as Mr. Roy Anderson mentioned, which will permit aircraft using the same airborne devices to receive satellite services anywhere around the globe.

We have come far in providing the technical foundation for a new service, that has already been touched on here, called automatic dependent surveillance, which in its first application may provide aircraft flying over the oceans a surveillance and communications service nearly equivalent to that available from radar when they fly over domestic airspace such as the United States.

FAA's involvement in satellite technologies for aviation began in the very early 1960's. There isn't time today to go into detail about FAA's involvement of satellite activities. On the screen you will see a quick rundown of the activities that have been underway. I think there's too much there for you to read now, but there has been a great deal of activity over the last 25 years.

[Slides shown.]

Suffice it to say that a large number of studies and developments, analyses, and tests, as laid out on the Vu-Graphs, were conducted. I can provide the subcommittee, if you wish it, sir, with a detailed summary for the record which expands somewhat on these items.

Mr. BROWN. I would appreciate it if you would do that, Mr. Poritzky.

[The material referred to follows:]

September 19, 1986

# CONSIDERATION OF THE USE OF SATELLITES IN THE AIR TRAFFIC CONTROL SYSTEM A REVIEW OF FEDERAL AVIATION ADMINISTRATION ACTIVITIES, 1961-1986

## INTRODUCTION

Since the dawn of the space age, which began with the launch of the first satellite in 1957, there has been interest in applying satellite technology to the nation's Air Traffic Control (ATC) system. The Department of Transportation (DOT) and the Federal Aviation Administration (FAA) have long supported research and development in this field. This paper briefly reviews the long trail since 1961 when FAA considered first the technical feasibility of using satellites, and later, as satellite technology began to mature, the application of satellites in the context of technical and cost/benefit tradeoffs.

### Early Activities (Oceanic Area Related) 1961-1982

FAA consideration of the potential application of satellites for ATC use dates back to Communication, Navigation, and Surveillance (CNS) related studies directed at oceanic applications begun in 1961 (1, 2, 3). FAA involvement in air ground communication tests dates back to 1964 when the FAA worked with the Air Transport Association of America (ATA) and Pan American World Airways in a pioneering experiment (4). Very High Frequency (VHF) data link communications were received onboard an inflight Pan Am aircraft from the National Aeronautics and Space Administration (NASA) Synchronous Communications (SYNCOM) Satellite Number 3.

In 1965, FAA initiated a program to determine the feasibility of satellite communications for over-ocean ATC use. Experiments were pursued to gather empirical data to substantiate theoretical performance estimates for satellite communications.

In late 1966, in parallel with airline-industry-sponsored VHF tests, the FAA participated with its own test aircraft in VHF air/ground experiments using the Nimbus II weather satellite (5).

In mid-1967, the FAA utilized its own jet aircraft to conduct VHF voice intelligibility, data-link performance, and multipath tests using the NASA Applications Technology Satellite Number 1 (ATS-1) (6).

While none of these ATS-1 tests were comprehensive or conclusive, they showed that even with the very limited signal power from ATS-1, both voice and data link VHF air/ground communications were possible. Given proper design, operational air/ground satellite communications were clearly feasible.

While FAA and the airlines continued investigations using the VHF frequency band for air/ground communications, the potential advantages of the aeronautical L-Band (1545-1660.5 MHz) were also being considered (7).

Europe was strongly in favor of L-Band, in large part because of the saturation of the VHF band in Europe and the concern that the introduction of satellite service at VHF would impede the future transition to L-Band. After lengthy investigation of the performance characteristics of L-Band, the White House Office of Telecommunications Policy, in January 1971, directed that L-Band be used for future oceanic applications (8), because it was considered superior to VHF.

In the early 1970's, two significant L-Band satellite-based flight-test experimental programs were sponsored by the FAA using the NASA ATS-5 and ATS-6 satellites (9, 10). These tests investigated multipath effects, the performance of voice and data communications, the characteristics of various ranging techniques, and the performance of a number of aircraft antenna systems under various operating conditions.

Unfortunately, ATS-5 malfunctioned and continued spinning after launch, thus providing a pulsed transmission not suitable for voice tests. ATS-6 was launched successfully, and both technical and ATC demonstration tests were performed. The ATS-5 program was conducted in 1971-73, in conjunction with Canada; the ATS-6 program in 1974-75 included both separate tests and joint test with Canada and the European Space Research Organization (ESRO), now the European Space Agency (ESA). These programs again demonstrated the feasibility of using satellite communications for air/ground ATC applications, and provided data useful for specifying system design parameters and predicting operational performance.

A number of technical, operational, and cost studies related to the feasibility, design, implementation, and operation of oceanic aeronautical satellite communication systems have been performed by, or sponsored by FAA (11-16).

In the early 1970's, the FAA worked with many countries to establish a basis for the possible future operational use of satellites for oceanic air/ground ATC communications (17). In August 1974, a Memorandum of Understanding (18) was signed by Canada, ESRO (representing ten European states), and the United States for the establishment of an experimental program called the Aeronautical Satellite Program (AEROSAT). This program was to plan, implement, test, and demonstrate aeronautical satellite communications capabilities, including both technical and operational techniques.

The AEROSAT program was to launch two geostationary satellites for coverage of the Atlantic Ocean, South America, and Africa. Consideration was given to the future movement of one of the satellites to cover the Pacific Ocean area. In addition to the L-Band communications payload, the satellites were to include a VHF capability desired by U.S. airlines and to be funded by the U.S., to provide an impartial evaluation of L-Band versus VHF.

The AEROSAT program suffered a number of schedule delays, and legal and funding difficulties. The estimated costs for the satellites increased greatly as the program proceeded, causing user and Congressional concern. The user community was troubled by who would pay for the AEROSAT space segment, with user charges looming as a possibility. The user community was also concerned that once such a costly, highly capable resource was implemented, operational use might be mandated, resulting in an expensive avionics retrofit for the airline fleet.

There were practical problems of need as well: The predicted operational supersonic aircraft fleet did not materialize; the anticipated growth in traffic did not occur, in large part due to the introduction of wide-body jet aircraft; the introduction of single-sideband high frequency radio equipment improved oceanic communications; and the wide use by the airlines of inertial navigation systems resulted in improved navigation performance. It was practical to obtain system improvements such as separation minima reductions without a satellite system. The first energy crisis added yet more financial uncertainty in the airlines' view.

In 1977 Congress chose not to continue funding for the AEROSAT program. Instead, Congress directed FAA to once again study the requirements for such services, and appropriated about one million dollars for the effort. The U.S. subsequently proposed to its AEROSAT program partners, in late 1977, that the AEROSAT program be restructured consistent with Congressional direction. The program was to: (1) reevaluate the requirements for a satellite program, (2) determine the time scale associated with the need (if any) for an operational satellite system, and (3) develop a milestone chart detailing development and transition to an operational system.

In early 1978 the AEROSAT Council, the administrative head of the program, accepted the U.S. proposals, and established "the Committee to Review the Application of Satellite and Other Techniques to Civil Aviation," known as the Aviation Review Committee (ARC). The FAA developed a study plan to investigate ATC system improvement for oceanic areas through the development and evaluation of potentially viable improvement alternatives including, but not limited to, the consideration of satellite technology.

In late 1978, the FAA, with the guidance of the ARC, began this study called the Oceanic Area System Improvement Study (OASIS), which was the primary resource of the ARC. This investigation concentrated on potential improvement alternatives for the North Atlantic, the Caribbean, and the Central East Pacific for the period out to 2005.

The ARC coordinated study program, with participation from twenty States and international organizations found that the largest potential savings would result from a reduction in vertical separation from 2000 feet to 1000 feet for aircraft operating above 29,000 feet (19, 20). The ARC's investigation of satellite options indicated that only a shared satellite service (i.e., not using a dedicated aeronautical satellite) providing a data-link-only service may be cost effective, with residual voice for emergency and non-routine use being provided by existing high frequency radio. These and other results of the ARC study program and a brief review of of this activity have been summarized (21).

Continental U.S. and Other Activities - Beginning Late 1960's

The DOT in 1968 formed the Air Traffic Control Advisory Committee (ATCAC) "for the purpose of recommending an Air Traffic Control (ATC) system for the 1980's and beyond" (22). The Committee drew heavily for technical support from FAA, NASA, DOD, and the aviation community, and maintained close liaison with many aviation organizations (23).

ATCAC included in their investigations an analysis of the feasibility and potential benefits associated with the use of satellite concepts. Their deliberations included postulating representative satellite systems for both the oceanic areas and the Continental U.S. (CONUS). In its recommendations, the "Committee review of future possibilities identified space and computer technologies as offering the greatest potential advantages by making possible universal coverage, greatly enhanced accuracy, ample capacity, and much higher levels of automation" (24).

As a result of the ATCAC recommendation, the DOT in 1970 initiated a comprehensive four-year investigation of advanced techniques, particularly satellites, for air traffic management. These studies, called the Advanced Air Traffic Management System (AATMS) studies (25-26) showed that satellite-based ATC systems were technically feasible for both CONUS and adjacent Oceanic applications. However, the systems were found to be considerably more costly than ground-based systems. The greater potential for improvement of the ATC system was attributed to automation.

In 1972 the FAA developed a satellite system concept called Astro-DABS (27, 28). This effort extended through 1975 and analyzed a satellite-based ATC system which was aimed at providing an evolutionary bridge using the newly configured Discrete Address Beacon System (DABS). DABS was the selection of the ATCAC as the system to provide the needed surveillance improvements to the existing ATC system. The DABS was later reconfigured and renamed Mode S. Although it was not found feasible at the time to use the evolving DABS signal structure in a satellite surveillance system, various techniques were investigated for providing satellite-based surveillance, navigation and data link services for ATC. The last concept investigated involved a constellation of seven satellites for CONUS coverage and employed avionics operating in the aeronautical L-Band (29).

The FAA has participated in and has supported, since 1976, an interagency committee charged with the preparation of the Federal Radio Navigation Plan (FRP). The FRP (30) includes an examination of civil-use navigation capabilities of present and planned navigation systems, including the Global Positioning System (GPS) satellite navigation system, and addresses the potential for reducing the cost of navigation systems supported by the U.S. Government while maintaining desired capabilities.

The development of the GPS has been monitored by the DOT and the FAA since the initiation of the GPS program in 1971. In 1978 FAA investigated satellite-based concepts for surveillance, communications, and navigation for CONUS, using the proposed GPS combined with a set of geostationary satellites (31). The FAA has investigated the cost of GPS receivers (32) and sponsored the development of low-cost GPS receiver system techniques (33). In carrying out the work, the coverage provided by the GPS and the acceptability of the system for civil use have been evaluated in substantial detail.

Other GPS related evaluation work included analysis of the monitoring and calibration network requirements, the determination of system reliability and the investigation of techniques for the integration of GPS receivers with other aircraft equipment. Flight tests of available GPS receivers have been conducted at the FAA Technical Center. Results indicate that the accuracy of GPS could be better than 100 meters 2d rms and that the Standard Positioning Service (SPS) civil signal has the inherent accuracy potential to support non-precision approaches (34). There are still questions concerning both the coverage available from the planned satellite constellation and the overall system integrity and reliability. Analysis in these areas are continuing.

Recent Activities, Current Work, and Future Efforts

Since 1982, FAA has investigated the feasibility of using the Mode S signal format in a satellite-based surveillance, navigation, and data link communication system (35). The initial feasibility study was extended to a more extensive system tradeoff study of surveillance techniques using satellites, which included performance and cost considerations (36). This study showed that it would not be cost effective to implement a satellite system which could be used directly with the planned Mode S Transponders, since very large and costly satellites would be required.

The FAA has also investigated the feasibility and cost of using satellite communications for point-to-point services, such as interfacility communications. While FAA currently uses satellite communications in the Pacific and in Alaska for point-to-point services, the broad use of satellite services in CONUS has not been shown to be cost-effective for the near future. In the post 2000 time period, ATC system productivity improvements may involve the exploitation of satellite technology, since satellite technology provides the potential to consolidate and disseminate data in a flexible manner.

In early 1984, at the request of various States and international organizations, the International Civil Aviation Organization (ICAO) agreed to undertake and extend the work begun by the Aviation Review Committee on the study of oceanic area system improvements. ICAO established the Future Air Navigation Systems (FANS) Committee of the ICAO Council to address this work. (In the ICAO forum, the term "air navigation system" takes into consideration communications, navigation, and surveillance). The scope is global, thereby extending the work both in terms of the geographic areas and the types of airspace to be considered.

The FANS Committee developed its work program in 1984 and held its first working meeting in July 1985. The FANS Committee is pursuing system improvements identified by the ARC, such as Automatic Dependent Surveillance (ADS), and developed a tentative future system concept regarding the provision of communication, navigation, and surveillance services looking ahead to the year 2010. In conjunction with this future system concept, the Committee developed service and air traffic requirements that would need to be satisfied by the future system. The U.S. provided a significant input into the concept and the requirements development process, which originated from the work of an FAA task group completed in early 1985 (37). A number of areas representative of the world traffic types have been identified; traffic scenarios are being developed using data from these areas with which to evaluate future system design proposals.

Included in the tentative future system concept is the projected use of satellite services including the provision air/ground communications and automatic dependent surveillance. The FANS Committee is presently developing an approach to a satellite communications architecture and system structure which would ensure the interoperability to allow an aircraft with a single type of avionics to operate around the world using various appropriate satellites that may be available.

The basic intention is to establish a satellite system structure which can efficiently meet, or can evolve to meet, the requirements and needs of aviation. This system concept must permit evolution from relatively simple applications to the more complex--a concept in which all elements of aviation can participate, from general aviation to air carrier and military, and which can serve areas from lowest density remote areas to oceanic use to high-density domestic terminal airspace. The system concept and structure must have the capability to work compatibly and efficiently with terrestrial services, which will no doubt remain in the picture, and must lead to the simplest practical avionics suite for the future. The goal is to achieve an international system which permits aircraft to take advantage of satellite communications services efficiently from a variety of providers based on an internationally agreed system architecture--a service which, within the same system concept, can meet the requirements of the air traffic control services as well as the uses to which air transport operators may wish to put such a system (operational control, administrative communications, passenger telephone, etc.).

In the U.S., The Radio Technical Commission for Aeronautics (RTCA) Special Committee 155 (SC-155) has been working in parallel with the FANS Committee effort. This RTCA Committee on "User Requirements for Communications, Navigation, and Surveillance Systems, including Space Technology Applications" was initiated in early 1984 at the request of FAA to establish a forum aimed at providing a broad U.S. user community input into the FANS Committee preparatory process, which develops U.S. positions for this activity. RTCA SC-155 is presently in the process of issuing a final report on its study efforts.

The FAA has and will continue to work within the FANS Committee and seek domestic inputs to progress ATC improvements in a systematic manner. The future application of satellites to support air/ground satellite communications and other services will depend upon a number of factors, including prominently their contribution to aviation safety, as well as the clear indication of cost-benefit to the users. FAA has efforts underway to detail CONUS and oceanic requirements for satellite-based air/ground communication services, including integrity and reliability, in support of the development of necessary standards.

DOT/FAA has maintained a broad base of information and knowledge in satellite systems and their application to air traffic control. Our goal is to investigate fully the options available for ATC through the use of satellite systems and to take maximum advantage of feasible, capable, and cost-effective techniques as they evolve.

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Mr. PORITZKY. Thank you.

In addition, as has again been mentioned, many other pioneering studies and tests were conducted by the National Aeronautics and Space Administration, DOD, and the industry. Virtually all the studies, even from the relatively earliest times on that Vu-Graph, showed that satellite applications to air traffic control were technically feasible and could yield benefits, but cost projections were so high that the aviation community was not motivated to move forward.

There was also a view in the early 1970's that the skies over oceans would become filled with airplanes, that there would be serious navigation and communications problems, and that the dramatic growth of operations, particularly with the anticipated large number of supersonic transports that we were then anticipating, would require a dramatic change in oceanic air traffic control services.

An agreement was developed in 1974 among European states, Canada, and the United States to develop and evaluate an aeronautical satellite communications system predominantly for overocean applications called Aerosat, but as the work progressed on that program, estimates of cost rose sharply. The prospect of large numbers of aircraft, including SST's, having to operate with inadequate navigation and inadequate communications diminished.

Communications improved with the introduction of high-frequency, single sideband communications. Navigation improved markedly with the introduction of inertial navigation systems which followed the Doppler systems. Airlines, which had been initially enthusiastic about satellite service, became increasingly concerned. Congress chose not to appropriate Aerosat project funds and directed FAA to reexamine the requirements.

With the termination of the Aerosat project in the late 1970's, an international group was formed called the Aviation Review Committee to review the requirements for new systems and new technologies for overocean operations, especially satellite technologies. The committee identified a number of improvements, especially to oceanic operations, which could yield higher efficiency to the air transport system including, but by no means exclusively or even predominantly, satellite services.

With the strong lead of the United States and support from the international aviation community, the International Civil Aviation Organization, ICAO, established the Future Air Navigation System—FANS—Committee that you have already heard about, to help implement the several major recommendations which grew out of the Aviation Review Committee and to look beyond at the new technologies.

Major progress has been made in the development, as I have already noted, of the concept, the operational use, and the technical characteristics for automatic dependent surveillance, or pseudo-radar, for first use over oceans. FAA is hard at work on a program to provide this new and potent capability to the controllers. The basic computation, data processing, and display system that will serve this function is under contract now.

Progress has also been made on the development of an internationally agreed standard satellite communications architecture and system structure, which Mr. Anderson and Mr. King described.

Because of the rapidly evolving satellite communications industry and the growing competition between countries in providing such services, along with a new prospect—and it is a new prospect—of reasonably priced services, FAA mounted a major effort to achieve U.S. agreement first and then agreement in ICAO FANS.

Let me interject two points here.

In all of this activity, Mr. Brown, the FAA Administrator, Admiral Engen, was very conscious of the importance of putting a best U.S. foot forward. We have a large satellite industry, it's very diverse, whereas some of our competitors—and there are three of them that are easily identified: Europe, the Soviet Union, and Japan—are considerably more unified in the approaches they take to these things. So it was Mr. Engen's wish, one, to have competition; and, two, to create a system which would, in fact, involve the prospective satellite services providers and help put the best U.S. foot forward.

I have dwelt on the international aspects, and I do so because satellites, usage, unlike much of the rest of our technology, has to be an international endeavor. Satellite services are best used when they are used regionally or worldwide, as you have already heard, so that international agreement, we think, is essential.

As I said, we mounted a major effort to try to get U.S. agreement and then an ICAO agreement. Our intention is to establish a satellite system structure which can efficiently meet or can evolve to meet the requirements and needs of aviation as already established by the ICAO FANS Committee which, as you have heard, was in significant degree based on the work that RTCA did for us.

The system must permit evolution from relatively simple applications to the more complex, a concept in which all elements of aviation can participate, from general aviation to air carrier and military, and which can serve areas from the lowest density remote areas to oceanic use to high density domestic terminal airspace.

The system must have the capability to work compatibly and efficiently with terrestrial services, as you've already heard, which will no doubt remain in the picture. It must lead to the simplest practical avionic suite for the future.

The goal is to achieve a system which permits aircraft to take advantage of satellite communications services efficiently from a variety of providers based on an internationally agreed system architecture, a service which can meet the requirements of the ATC services as well as the uses to which air transport operators may wish to put such systems.

Now I noted, and you've already heard, that the FAA Administrator asked for, and received generous support—technical support—from interested prospective satellite providers. Earlier this year also, we established a group of Government experts from various agencies—NASA, the Transportation Systems Center, JPL, FAA—to help develop an optimum system structure and architecture to serve aviation's needs, for us to take to the international forum. There is reason to hope, we believe, that it may be possible to reach substantial agreement on such a system architecture and

structure at the November 1986 full meeting of the ICAO FANS Committee.

The initiatives I've described lead to another matter, the question of future institutional and management arrangements for aviation services. Implementation of air navigation services around the world is far from uniform. In many parts of the world, services desired and needed by air transport operators simply have not been implemented because of lack of funds, lack of trained personnel, or other reasons.

New technology and, to some degree, existing technology could help leapfrog a number of problems. There was some discussion of leapfrogging earlier. In a remote area of the world, where current services are either inadequate or absent, that leapfrog is a very real possibility. It is much easier in much areas than to consider leapfrogging the services now available in Des Moines, IA, which really aren't bad.

We think it's conceivable that the new technology systems can reduce the extent of maintenance, operations, logistics, infrastructures, and eliminate the need for land lines and buildings, perhaps first in the remote areas and probably much later in developed areas of the world. There is a problem, the very regions of the world where such services would be of greatest value are also areas where money is scarce, while areas of the world which might be able to afford such new services already have adequate, not perfect, but in many instances adequate, primarily ground-based systems.

FAA therefore believes that the implementation of new capabilities and services must be done in such a way that the user communities in the United States and abroad themselves recognize their importance. Methods then need to be developed for transition from existing services and capabilities to these new technologies. Our history is one of evolution.

It is not a foregone conclusion that satellite services must be provided by the Government. Our efforts are intended to reach agreement domestically and internationally on the minimum technical standards that such new technology systems must meet in order to be viable elements of the air traffic control service. We look to a healthy competition by both domestic and international entities in the actual provision of the services.

Up to now, I've spoken little about navigation. As you've already heard, there is a major investment—and you know this probably better than I—in the global positioning system—GPS—a multisatellite, high-quality navigation system. FAA has been studying GPS for a number of years, and we believe it has a bright future in civil aviation. It overcomes the line-of-sight restrictions of many of our present navigation aids. It is expected that a global satellite navigation system such as GPS will be able to provide accurate information and coverage from essentially ground level to the highest altitudes at which we expect aircraft to operate.

President Reagan, shortly after the tragic downing of KAL-007, stated that GPS services would be made available to world civil air transportation, and it could come to serve as the basis for the automatic dependent surveillance service that I've mentioned—probably not in the beginning, but later on in the century.

The Soviet Union is also developing a system which has the appearance of being similar to GPS, a system called GLONASS, and studies of other similar navigation satellite systems are under way in Europe. I mention it just to point out we're not alone out there—either in the navigation world or in the provision of the other services.

We continue to work both internationally and with the Department of Defense to help make GPS a viable, sole means navigation system for the future.

We believe satellite technology will have an important role in the future civil system, and we continue our research, development, and analysis efforts to find the best, most cost-effective ways to take benefit from these capabilities.

We think that the days of basic research are past. Our work will concentrate on assessing the best ways to utilize the technology in a system evolution which permits taking benefit from the new systems without disadvantaging the present system's capability.

Our planned work will concentrate, as has already been mentioned, on the work remaining to support utilization of GPS in the National Airspace System. We will work to obtain the best information necessary for the most beneficial and technically sound use of satellite-based air/ground communication systems for both voice and data communications.

Satellite communications relay services between FAA facilities are already in use, usually provided through leased services. We will continue to explore satellite-based technology for interfacility, point-to-point communications. We will concentrate on the technologies beyond those now available, and we continue to look for output from the work that NASA is doing, that you touched on a moment ago. We will work to examine the best mixes of satellite and terrestrial communications in the aviation system of the future.

I'd like to close, Mr. Chairman, with two observations. It's already been said here that we have been at work for several years on the major system modernization, the National Airspace System Plan. It is moving forward aggressively, it will provide a major modernization to the benefit of the flying public and to the operators who use the National Airspace System. Modernizations are under way as well in a number of other parts of the world.

These modernizations form the foundation on which the new technologies may be exploited. They are not a substitute for the modernizations.

In the formulation of the NAS plan, FAA was aware that new technologies were coming along, not only satellite but, perhaps more importantly, computer technology and fundamental changes in communications technology. Our NAS plan forms the essential base on which the new technologies can be beneficially used.

The second point I'd like to make is a recognition of the role satellite technology or other new technologies can play in the evolution of the air traffic control system. They are not a panacea but will work best in a synergistic partnership with terrestrial systems.

If you look at the viewgraph, you will find a distinction which is absolutely critical. The air traffic control service, at the bottom consists of controllers, procedures, automation, computers, interfa-

cility communications, flow management, as a very simplified description.

The supporting services—the air-ground communications, the navigation services, the radar, the secondary radar, are the eyes and ears of that system. Satellites are likely to become, at least in part, the new eyes and ears of that system, but they are not a substitute for ATC. They can only be the helpers, the sensors that make the air traffic control system work.

The automation system, an essential ingredient in taking advantage of the improved information flow that these new technologies can give, has to be there and has to be there first. The automation system, contrary to what was said here earlier, doesn't really care much where the information comes from—from outer space or from a radar—as long as that information is highly reliable, accurate, and timely.

Satellite communications and surveillance, and perhaps navigation, all improve the information flow between aircraft and the air traffic control system, and permit the air traffic control process to be more efficient. In our modernization efforts, we will continue to consider cost-effective and beneficial application of satellite or other technologies to enhance the eyes and ears of the air traffic control system.

Mr. Chairman, that concludes my prepared statement. I'd be pleased to answer any questions which you may have.

[The prepared statement of Mr. Poritzky follows:]

STATEMENT OF SIEGBERT B. PORITZKY, DIRECTOR, SYSTEM STUDIES AND COOPERATIVE PROGRAMS, FEDERAL AVIATION ADMINISTRATION, BEFORE THE HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY, SUBCOMMITTEE ON TRANSPORTATION, AVIATION AND MATERIALS, CONCERNING THE USE OF ADVANCED SATELLITE SYSTEMS FOR GLOBAL AIR TRAFFIC CONTROL AND NAVIGATION--SEPTEMBER 24, 1986

Mr. Chairman and Members of the Subcommittee:

I welcome this opportunity to review for you FAA's involvement in advanced satellite technology for air traffic control and navigation.

Nearly 30 years after the launch of the first satellite and nearly 25 years after FAA became active in the study of satellite applications, the great potential of satellite services to civil aviation may soon begin to be realized. The FAA believes that satellites are likely to play an important role in the improvement of air traffic services around the world.

We are close to achieving international agreement on a satellite communications architecture and system structure which may permit aircraft, using the same airborne devices, to receive satellite services anywhere around the globe. We have come far in providing the technical foundation for a new service called Automatic Dependent Surveillance (ADS) which, in its first application, may provide aircraft flying over oceans

a surveillance and communications service nearly equivalent to that available from radar when they fly over domestic airspace such as the United States.

FAA's involvement in satellite technologies for aviation began in the very early 1960's. The first practical application development of satellites for air traffic control air/ground communications dates back to 1964, when FAA worked with the Air Transport Association of America (ATA) and Pan American World Airways in a pioneering experiment. There is not time to go into detail about FAA's involvement in satellite activities, but I can provide the Subcommittee with a detailed summary for the record. Suffice it to say that a large number of studies and developments, analyses, and tests, as laid out on the vu-graphs (VG-1, 2, and 3), were conducted. In addition, many other pioneering studies and tests were conducted by the National Aeronautics and Space Administration and industry.

Virtually all of the studies showed that satellite applications to air traffic control were technically feasible and could yield benefits, but cost projections were so high that the aviation community was not motivated to move forward.

In the early 1970's, several experimental programs showed that satellites could be used for air/ground communications. There

also was a view that the skies over oceans would become filled with airplanes, that there would be serious navigation and communications problems, and that the dramatic growth of operations, particularly with the anticipated large number of supersonic transports, would require a dramatic change in oceanic air traffic control services.

FAA felt that satellite communications would become attractive and strove to have a satellite communications service in place before the expected problem became acute. After negotiation, an agreement was developed in 1974 among European states (represented through what is now the European Space Agency), Canada, and the United States, to plan, develop, and evaluate a hybrid VHF/L-Band experimental oceanic (Atlantic) aeronautical satellite communication system, called AEROSAT.

As work progressed, estimates of costs rose sharply. The prospect of large numbers of aircraft, including SST's, having to operate with inadequate navigation and inadequate communications diminished. Communications improved with the introduction of the High Frequency Single Side Band. Navigation improved markedly with the introduction of inertial navigation systems.

A difficult question revolved around who would pay, and how, for a potentially expensive satellite communications and surveillance service. Airlines, initially enthusiastic, became

increasingly concerned. Not everyone was saddened by this development. Congress subsequently chose not to appropriate AEROSAT project funds and directed FAA to reexamine the requirements.

With the termination of the AEROSAT project in the late 1970's, an international group, the Aviation Review Committee, was formed to review the requirements for new systems and new technologies for over-ocean operations, especially satellite technologies. This group solicited the support of international airlines, along with experts from many countries. The committee identified a number of improvements, especially to oceanic operations, which could yield higher efficiency to the air transport system. They believed that satellite services, because of their unique capabilities, would have a place in the aviation system, that the capacity requirements for over-ocean air traffic control satellite communications were real but modest, and that the most viable way to achieve such services probably would be by sharing with other prospective satellite users to constrain costs.

With the strong lead of the United States and support from the international aviation community, the International Civil Aviation Organization (ICAO) established the Future Air Navigation Systems (FANS) Committee to help implement the several major recommendations which grew out of the Aviation Review Committee.

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It had become apparent that improved oceanic communications and automatic dependent surveillance (ADS) services, initially over oceans, could have a major positive impact on the safety and efficiency of aircraft operations, and that a uniform worldwide standard satellite communications method would be required to use automatic dependent surveillance beneficially. (Automatic dependent surveillance is a function in which aircraft automatically transmit data derived from on-board navigation systems via data link to an air traffic control facility.)

Major progress has been made in the development of the concept, the operational use, and the technical characteristics for automatic dependent surveillance, or "pseudo-radar," for first use over the oceans. FAA has worked closely with the Airlines Electronic Engineering Committee (AEEC), which is already developing avionics standards to include the automatic dependent surveillance capability in aircraft systems. FAA is also hard at work on a program to provide this new and potent capability to the controllers.

Progress has also been made on the development of an internationally agreed standard satellite communications architecture and system structure. In the effort to achieve an ICAO FANS agreement, FAA and the aviation community recognized several important factors:

- A basic satellite communications structure and system architecture must be agreed to internationally if aircraft are to be able to take benefit from such services.

- While it might be possible to achieve agreement on a satellite navigation system operated by one country or group of countries, communications and surveillance services are likely to be provided by regional groupings. Acceptance of an international satellite communications system standard is likely to be possible only if any country or group of countries has the opportunity to provide such services.

It has been recognized from the beginning that communications satellite services would be used for a variety of purposes, including air traffic control services, data link and voice communications.

Because of the rapidly evolving satellite communications industry and the growing competition between countries in providing such services, along with the new prospect of reasonably priced services, the United States must move rapidly to achieve agreement on a satellite system structure. FAA mounted a major effort to achieve U.S. agreement first and then agreement in ICAO FANS. The basis for FAA's work is the accumulated knowledge from the many studies I mentioned earlier.

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FAA Administrator Engen has expressed his conviction that 1) FAA should help airlines obtain such services effectively and soon, 2) FAA should stimulate beneficial competition in the provision of satellite services within a compatible structure, and 3) FAA should strive for a satellite system structure which has the capabilities described and has a chance for international agreement and standardization.

The intention is to establish a satellite system structure which can efficiently meet, or can evolve to meet, the requirements and needs of aviation as already established by the ICAO FANS Committee. This system must permit evolution from relatively simple applications to the more complex--a concept in which all elements of aviation can participate, from general aviation to air carrier and military, and which can serve areas from lowest density remote areas to oceanic use to high-density domestic terminal airspace. The system must have the capability to work compatibly and efficiently with terrestrial services, which will no doubt remain in the picture, and must lead to the simplest practical avionics suite for the future. The goal is to achieve an international system which permits aircraft to take advantage of satellite communications services efficiently from a variety of providers based on an internationally agreed system architecture--a service which can meet the requirements of the air traffic control services as well as the uses to which air transport operators may wish to put such a system.

It was recognized early that if different, noncompatible systems grow, implementation of useful satellite capabilities might be difficult.

The situation has been complicated by uncertainties about the frequency spectrum available to aviation. The recent action by the Federal Communications Commission (FCC) requires sharing of the spectrum with other services.

In our attempt to achieve a single U.S. proposal for a satellite system structure, we have worked closely with the major user organizations. FAA also asked for and generously received technical support from interested prospective U.S. providers of satellite services. The approach has been to create a system capable of sharing and of providing the nonsafety services on a secondary basis.

Early this year, FAA established a group of Government experts from various agencies to provide advice and input to FAA and to the FANS Preparatory Group to help assure an optimum system structure and architecture to serve aviation's needs.

There is reason to hope that it may be possible to reach substantial agreement on a system architecture and structure at the November 1986 full ICAO FANS meeting.

The initiatives described lead to another matter--the question of future institutional and management arrangements for aviation services.

While ICAO Regional Plans for implementation of facilities and services have been used for more than 35 years, implementation has been far from uniform. In many parts of the world, services desired and needed by air transport operators simply have not been implemented because of lack of funds, lack of trained personnel, and other reasons. The question is whether the institutional arrangements which have been in use for so many years need to be reexamined. The matter is complex. While countries can now provide services almost autonomously, the capabilities of new systems, particularly satellite systems with their broad coverage, will require new levels of cooperation if the systems are to be used beneficially. The desire of most air transport operators to make national boundaries transparent and the possibility of using satellite services in areas where services have been unavailable make the examination of the institutional and management issues important.

New technology and, to some degree, existing technology could help leapfrog a number of problems. For example, satellite earth stations for communications and possibly position location could obviate the need for locally operated sophisticated telephone or radar systems. Satellite navigation

would obviate the need for an extensive network of ground navigation aids. It is conceivable that new technology systems could reduce the extent of maintenance/operations/logistics infrastructures and eliminate the need for land lines, buildings, etc.

Yet, the very regions of the world where such services would be of greatest value are also areas where money is scarce, while areas of the world which might be able to afford such services already have adequate, primarily ground-based systems.

A whole series of problems arise. While countries where services are now limited could leapfrog current technology by the use of satellite sensor systems, the new systems might well be technically incompatible with existing systems in wide use in other parts of the world unless a clear and attractive transition method can be achieved.

FAA therefore believes that the implementation of new capabilities and services must be done in such a way that the user communities themselves recognize their importance. Methods would then need to be found to transition from existing services and capabilities to these new technologies.

It is not a foregone conclusion that satellite services must be provided by the Government. Our efforts are intended to reach

agreement domestically and internationally on the minimum technical standards that such new technology systems must meet in order to be viable elements of the air traffic control service. We look to a healthy competition by both domestic and international entities in the actual provision of the services. While most of the states of ICAO believe that the actual control of aircraft must be under the jurisdiction of the cognizant air traffic control authority, technical systems which provide the basis for control may be provided by international commercial entities. The FAA encourages such competition.

Up to now, I have spoken little about navigation. There is a major U.S. investment in the Global Positioning System (GPS), a multi-satellite, high-quality navigation system. FAA has been studying GPS for a number of years and we believe it has a bright future in civil aviation. It overcomes the line-of-sight restrictions of many of our present navigation aids. It is expected that a global satellite navigation system, such as GPS, will be able to provide accurate information and coverage from essentially ground level to the highest altitudes at which we expect aircraft to operate. GPS, in its present state, is not able to provide navigation capability to serve as the "sole means" of air navigation, but we expect that the evolution of this system in the next few years will permit its use as such, and we will work to that end. President Reagan, shortly after

the tragic downing of the Korean Airlines Flight 007, stated that GPS services would be made available to world civil air transportation, and it may come to serve as the basis for the Automatic Dependent Surveillance service. While we believe that GPS has a bright future in civil aviation, others are at work on similar systems. The Soviet Union is developing a system which has the appearance of being similar to GPS--a system called GLONASS--and studies of other, similar navigation satellite systems are underway in Europe. We continue to work both internationally and with the Department of Defense to help make GPS a viable, sole-means navigation system for the future.

We believe satellite technology will have an important role in the future civil system and we continue our research, development and analysis efforts to find the best, most cost-effective ways to take benefit from these new capabilities. We think the days of basic research are past; our work will concentrate on assessing the best ways to utilize the technology in a system evolution which permits taking benefit from the new systems without disadvantaging the present system capability.

Our planned work will concentrate on the work remaining to support utilization of GPS in the National Airspace System. We will work to obtain the best information necessary for the most beneficial and technically sound use of satellite-based air/ground communications systems to be used for air traffic

control voice and data communications. Satellite communications relay services between FAA facilities are already in use, usually provided through leased services. We will continue to explore satellite-based technology for interfacility point-to-point communications. We will, of course, concentrate also on the technologies beyond those now available. We will work to examine the best mixes of satellite and terrestrial communications in the aviation system of the future.

I would like to close with two observations. FAA has been at work for several years on a major system modernization--the National Airspace System Plan. It is moving forward aggressively and it will provide a major modernization to the benefit of the flying public and the operators who use the National Airspace System. Modernizations are underway as well in a number of other parts of the world. These modernizations form the foundation on which the new technologies may be exploited, they are not a substitute for the modernization. In the formulation of the NAS Plan, FAA was aware that new technologies were coming along, not only satellites but also computer technology and fundamental changes in communications technology. Our NAS Plan forms the essential base on which the new technologies can be beneficially used.

The second point, equally important, is a recognition of the role satellite technology or the other new technologies can play in the evolution of the air traffic control system. (VG-4)

They are not a panacea, but will work best in a synergistic partnership with terrestrial systems. It is sometimes asserted by enthusiastic advocates that satellites might be used instead of the automation of the air traffic control system. Both are required. Satellite communications and surveillance, and perhaps navigation, all improve the information flow between aircraft and the air traffic control system and permit the air traffic control process to be made more efficient. In our modernization efforts we will continue to consider cost effective and beneficial application of satellite and other technologies to enhance the eyes and ears of our air traffic control system.

Mr. Chairman, that concludes my prepared statement. I would be pleased to answer any questions which you or other members of the Subcommittee may have.

# FAA Satellite Activities

- 1964 Coordination With ATA and PAN AM in VHF DL Comm Through NASA Syncom 3 to In-Flight Aircraft
- 1965 Initiated R&D Program on Feasibility of Satellite Communications for Over-Ocean Use
- 1966-67 VHF Voice and Data Tests, With Nimbus-2 and ATS-1
- 1968-69 Air Traffic Control Advisory Committee Investigated Satellite System Concepts for CONUS and Oceanic Applications
- 1970-74 Multiple DOT Studies on Advanced Air Traffic Management Systems With Emphasis on Satellite-Based ATC
- 1971-75 Flight Test Experiment Programs Conducted With NASA ATS-5 and ATS-6 Satellites
- 1972-74 Independent Development of Astro-DABS
- 1974 MOU Signed for Aerosat Program With Canada and ESRO
- 1974-77 Aerosat Development; L-Band, VHF Communications and Surveillance for Oceanic Use (Atlantic)

# FAA Satellite Activities (Continued)

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|---|---|
| • 1976 | Sponsored Interagency Task Force on Satellite Systems, Re-Examined Potential of Satellite Technology for ATC. |
| • 1976-85 | Support of Interagency Committee for Preparation of Federal Radionavigation Plan |
| • 1978 | Investigation of Satellite-Based ATC Concepts for CONUS Using Navstar/GPS |
| • 1978-82 | Participation in "Committee to Review the Applications of Satellite and Other Techniques to Civil Aviation," for Oceanic Areas (ARC) |
| • 1978-85 | Evaluation of Navstar GPS Applications for Civil Aviation; Reliability, Integrity, Coverage. Development of GPS Civil Receiver and Flight Tests of Receivers at FAATC |

# FAA Satellite Activities (Continued)

| | |
|---|---|
| • 1982-85 | Analyses of Satellite-Based Surveillance; Mode-S Compatible and Other |
| • 1983-85 | Investigation of Future Technology Alternatives for Communications, Including Satellites |
| • 1985 | FAA Task Force Assessment of Satellite Concepts and Aviation Spectrum Requirements |
| • 1985-86 | Investigation of the Capabilities of Alternative Satellite-Based Position Determination Techniques for Aviation Applications |
| • 1985-86 | Development of U.S. Approach to an International Satellite Communications System Architecture & System Structure |
| • 1986 | Technical Investigation of Aeronautical Spectrum Sharing Techniques and Their Implications on Air Safety, Capacity, and Standards |

## *Supporting Services*

Air/Ground Communications

Navigation Services

Radar/Secondary Radar

The Sensors:
Eyes & Ears

## *Air Traffic Control*

Controllers
Procedures
Automation/Computers
Interfacility Communications
Flow Management

The Air Traffic
Control System

Mr. BROWN. Thank you very much, Mr. Poritzky. You make a very persuasive statement, and we appreciate it.

You heard the testimony from the General Accounting Office, Mr. Palmer, and the thrust, I think, of what he said was not in disagreement with your statement. The ideal here is, as you have expressed it, to have the NAS plan constitute a base on which we can utilize advanced technologies as they become available in a cost-effective way.

The question is—and he made the statement, and we're not going to exhaust it here, but just to open it up—that we have a window of opportunity here, that we perhaps ought to take advantage of that, look at the pace and direction of what we're planning to do under the NAS plan and see if it might require some modification or reorientation at this point. Would you like to comment on that?

Mr. PORTIZKY. Yes. Let me start and then ask Mr. Page to comment as well.

If you look at the NAS plan, it is of course not a static document. It has changed. There is an annual formal process of change and a review by Congress each year of the NAS plan. You will find in it some of the things that I've described. You will find in it, as I've mentioned, the oceanic data processing and display system whose expansion, not by itself, but whose expansion will serve the satellite services. You will find in it the beginnings of the application of GPS. Loran-C is a recent addition to the NAS plan. So it has evolved.

The matter that puzzles me is, what would you not do? Would you not do the major parts of the NAS plan, the mode S sensor, the data link, the improved weather services, the improved surveillance systems, and, most importantly, the advanced automation system? My answer to that would have to be a resounding no. Those programs must continue, because you can't do the new things until you've done these.

GPS has been talked about at great length. There is in the NAS plan work to improve the terrestrial navigation system, but the air traffic control system doesn't care very much whether an aircraft uses VOR or INS or GPS or Loran-C as long as a given capability in accuracy and reliability is achieved. There is no need to change the NAS plan to accommodate GPS other than to do the work necessary to achieve sole means and appropriate monitoring.

So my answer is that I believe the NAS plan must move forward as rapidly as possible. The potential for technology improvements has been recognized from the beginning, from the formulation of the plan in which both Mr. Page and I were involved.

Thank you.

Lee, would you—

Mr. PAGE. I'd just like to add one little thing. I think we opened that window of opportunity consciously 2 or 3 years ago when we asked RTCA to analyze the technologies. We have their report, we've reviewed it in detail, participated in it, and we have come to the conclusion, which I believe the committee also did, that we must press forward with the NAS plan as it stands. We are making adjustments for things like Loran-C when it looks like—or terminal

Doppler weather radar, when it looks like there's need for adjustment.

We'll make the accommodation to GPS, and other changes on an annual basis we do the reviews, and we think that, reinforced with the special committee report, we're on the right track. We can build the flexibility into the advanced automation system to accommodate satellite technologies for surveillance when they reach maturity.

Mr. BROWN. We're not going to urge you to slow down. The position of the Congress—at least the committees that I'm familiar with—has been to urge you to speed up on most of these things, but we also are concerned about some of the problems that were indicated, and of course we would expect, I think, in both of the pertinent committees in the House that are most concerned, to review this situation next year again and to see what opportunities might be available.

I am particularly concerned that there were four specific R&D items that are not being as perhaps adequately funded as might be necessary in order to allow for more adequate planning, and integration, and development of advanced technical systems, and I'd like to have you comment on that, Mr. Poritzky.

I know you're under pressure to save money on R&D, and I know you probably have to defend that, but we need to know if we can save money by making a prudent investment in the kind of research that those particular program elements cover.

Mr. PORTIZKY. Thank you, Mr. Chairman. I would make this comment. In the FAA RE&D Plan (Red Book) as you've already heard, there is a significant amount of work on the application of satellite technology. Should there be more? I believe the answer to that is yes. We've tried to identify additional things that must be done.

However, I want to say in the same breath that we have come far, based on the fruits of the 25 years of work that I showed on the screen. A great deal of work has been done. We are trying, in the development of the international satellite system structure that I mentioned, to take advantage of that work, to take advantage of what the aviation community is doing for itself, and the work of the satellite community.

We have a list, as we always do, of additional R&D work that we think will need to be undertaken. It is not gigantic in terms of money. Much of it is application-oriented—how do you use the technology that exists?

I might add one more point. As the RTCA work has proceeded, FAA, as you've heard, was an active participant. We listened carefully to what went on there. We have just recently completed something we've called An FAA Vision of the Future CNS system, which tries to draw the connection between the system as it is now and as it might be in the year 2010 or thereabouts. If it's your wish, we can make that available, sir.

Mr. BROWN. It is our wish that you make that available, Mr. Poritzky.

[The document follows:]

U.S. Department of Transportation

Federal Aviation Administration
Washington D.C.

9/19/86

# An FAA Vision of the Communications, Navigation, and Surveillance (CNS) Services in the Future Air Traffic Control System

## INTRODUCTION

Air traffic control and its supporting communications, navigation, and surveillance (CNS) services are anticipated to be significantly different in the 2010 timeframe than they are today. Air traffic management is anticipated to evolve in a number of world areas as the present system modernization programs, now planned or underway, are completed or are themselves improved upon.

The thinking presented here is the current FAA view of the future system based on technologies either available or anticipated within the timeframe considered. The communications, navigation, and surveillance services in the future Air Traffic Control System are intended to meet the anticipated requirements of the Air Traffic organization in the evolution of the air traffic management system. This work represents a snapshot in time, but an essential one for the development of plans for future research and development. While it represents FAA views based on present knowledge, it is expected that new technology and future development may change elements of the future system as envisaged. Exploratory research and development on alternatives must continue, and the future system can be expected to change as new technology matures and is shown to be beneficial and cost effective.

Communications, navigation, and surveillance systems are tools of the air traffic management system. It is not anticipated that such tools will evolve to replace the air traffic controller. Instead, they are ingredients in providing the basis for automation of the air traffic management system and improving the information flow which is the foundation for efficient air traffic management. The actual level of ATC automation will be driven by its acceptability to pilots and controllers.

This paper is not an attempt to design the future system in detail, but is a statement of desired capabilities and potential. The foundation for this view of the future system is the successful completion of the National Airspace System modernization; the concepts build on that foundation and assume that the capabilities expected at the end of that modernization are in place.

## 1. AIR TRAFFIC MANAGEMENT EVOLUTION

It is helpful to first consider the direction of evolution of the management and control of air traffic.

At the end of the U.S. National Airspace System (NAS) Plan modernization, and to varying degrees similar programs in other parts of the world, it is reasonable to assume that the information available to operators and the Air Traffic Control System on weather and winds will be improved dramatically. Information flow will be enhanced through wide use of digital data link communications, and dynamic knowledge of system capacity and airport capacity will have become good enough to permit a great deal more strategic planning than exists in the system today.

The Air Traffic Control System, which is today a balance of strategic and tactical operations, will have shifted to permit more strategic planning, but will be far more capable of adapting to changing traffic situations. The air traffic control process, through capabilities such as Automated En Route Air Traffic Control (AERA) or similar automation, will be far more automatic than it is today and will be on the way to permitting automatic creation and transmission of conflict-free clearances. AERA and the flow management system (TMS) will have been merged into a single system which extends from en route operations to the departure and arrival phases in the terminal area at major airports. Cockpits, especially in sophisticated aircraft, will evolve to give crews a better picture of their total situation. Cockpit systems which can simplify and optimize the interaction of pilots with automatic systems and digital communication devices will be in widespread use. This will result in a large population of aircraft with the ability to fly precisely enough to work with narrow metering "windows" established by ATC to use airport and airspace resources efficiently.

Operators will always wish to retain and increase their freedom to fly where and when they wish. However, traffic density will be so high and the vehicles so varied that discipline, by common consent, increasingly will be necessary in high-density airspace to achieve efficient operations for all users. Traffic management will be required in more airspace as traffic grows. Information flow and traffic management at the lower altitudes will become more critical because of increased numbers of commuters, rotorcraft, tilt-wings, and ultra-light aircraft. As aircraft enter higher traffic density airspace from low-density airspace, they will automatically become part of the controlled system, communicate their intentions if they have not done so before takeoff, and be "controlled" to the extent necessary to assure separation, avoid conflicts, and fit into the managed terminal area and airport situation.

Very high altitude control systems will come on the scene to permit safe management of aircraft operating in the supersonic and hypersonic regimes. While the basic process of air traffic control is not likely to change, management of aircraft in supersonic and particularly hypersonic regimes will require special handling, probably through use of very large coverage high-altitude centers, perhaps with international or multinational control. Such aircraft are likely to require strategic handling and precise landing time reservations to avoid low-altitude maneuvering or holding.

The concept of VFR operations will remain viable, but enhanced to reduce collision risk by a technical system which, normally passive, will warn all aircraft of impending conflicts and will be able to intervene, if necessary, to avoid conflicts particularly between VFR and IFR aircraft. Virtually all aircraft should have accessible to them near real-time weather data and other flight information, much of it via digital data link.

Easy, convenient, and cost-effective information flow will be the key not only to the evolution of CNS, but also the provision of improved air traffic control and weather services. It will make it possible for the system to have knowledge of virtually all aircraft for a variety of functions, including search and rescue. Such information and knowledge does not and should not presuppose control or management of aircraft flow where that is not demonstrably necessary.

## 2. FUTURE CNS SERVICES

The CNS system will undergo important changes. The system will need to be inherently capable of providing CNS services in essentially all the world's airspace, from the surface to at least 70,000 feet (and much higher as new supersonic and hypersonic aircraft appear on the scene), although the same level of services will not be implemented in all airspace.

### 2.1 Navigation

Navigation is likely to be based largely on a highly reliable, high-integrity, and high-accuracy global satellite-based navigation system, probably an evolution of the present Global Positioning System (GPS), with nearly instantaneous failure warning and enunciation. Three-dimensional information will be available, along with a standard system time service. This system will provide at least nonprecision approach capability everywhere. Precision approach and landing, and precision missed approach service, using straight-in, curved, and segmented approaches and departures will be provided by the Microwave Landing System.

While a global satellite system will be the primary navigation service, air traffic management, where practical, will be based on a minimum required navigation performance capability, and separation standards will be implemented based on navigation performance requirements suited to the application. Operators will be free to use other navigation systems which meet the mitimum requirements, and which they find suitable for their purposes.

While the satellite navigation system will provide vertical information, barometric altimetry will remain an important element in the system. Satellite-derived vertical information may become the primary altimetry means in the very high-altitude regime. Barometric altitude will remain the system standard in most airspace, but it may be possible that the geocentric altitude available from the satellite navigation system could serve as a crosscheck on vertical position in the lower portions of the airspace.

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2.2 Surveillance

Aircraft navigation systems will be of sufficient integrity to serve as a source for automatic dependent surveillance (ADS), in which aircraft-derived navigation position information is transmitted to the ground either directly or via satellite communications relay, to serve as a surveillance system for all airspace, with appropriate built-in redundancy and failure protection. Satellite navigation may eventually become the navigation source of choice for automatic dependent surveillance.

Automatic dependent surveillance alone may not fully meet the requirements for all airspace applications. Therefore, in addition, a need may exist for cooperative independent surveillance services.

For some airspace cooperative independent surveillance may be satellite-based, but terrestrial systems will continue to be the optimum choice in certain airspace, especially for high-density terminal areas.

Among the possible approaches are:

a. A constellation of satellites of which at least a number would be in nongeosynchronous orbits dedicated to this service. Aircraft would likely transmit short bursts of pulses including only aircraft identification information, which would be received by, and transmitted to the ground, from several satellites. This system could provide three-dimensional surveillance.

b. Another approach would be to use either available or dedicated geostationary communications satellites (at least two appropriately spaced satellites required for each area), adapted to provide synchronized ranging using the aircraft communications element in a transponding mode. Practical execution of this approach would require altitude information to be supplied by the aircraft in order to achieve two-dimensional surveillance information. While this cooperative independent surveillance scheme is the lesser-integrity system, it may be an adequate augmentation of automatic dependent surveillance (which itself can be buttressed by the use of both barometric and/or geocentric satellite-derived vertical information).

It is unlikely to be necessary or desirable to use satellite-derived surveillance in all airspace or in all terminal areas where cooperative independent surveillance is needed. For high-density terminal area situations, the system of choice is likely to remain terrestrially based. However, the terrestrially-based surveillance systems should be technically compatible and interoperable, to the extent possible, with space-based surveillance systems, in order to minimize aircraft avionics complement requirements.

The terrestrial cooperative independent surveillance service could be provided in a number of ways, beginning with SSR Mode S. Multilateration schemes may evolve to provide high-accuracy surveillance which can provide compatible airport surface guidance and control. Studies will be needed to identify functionally capable and cost-effective evolutions.

Primary radar is likely to remain on the scene for the civil aviation system, but will be used primarily for weather and severe weather detection.

2.3 Communications

It is anticipated that the bulk of ATC communications will use digital data link techniques to permit high efficiency in information flow. Data link communications are an essential ingredient in ATC automation, in permitting automatic communications between ATC system elements, and in facilitating the information flow which is the basic ingredient in improved ATC services. Voice capability will continue to be required to satisfy certain air-ground communications functional needs. While a limited voice capability will be required for en route areas, more voice communications is likely to be needed in terminal areas.

A satellite communications relay will be used extensively, but not necessarily exclusively, to provide the automatic dependent surveillance position information, along with additional information as required and available, such as aircraft identification, state and intentions, meteorological information, etc., and information concerning air traffic control services.

Communications services (data and some voice) between aircraft and the ground system will use satellite relay in over-ocean and remote land areas, at altitudes below line-of-sight in both low-density and high-density airspace, and for other purposes.

In some airspace, such as high-density terminal areas, the bulk of communications is likely to be such that terrestrial direct air-ground communications will be preferable to a satellite-based communications systems. The terrestrial services and the satellite-derived services will, however, need to be technically compatible and interoperable, to the extent possible, in order to minimize the avionics system complement.

Several benefits will result from the use of terrestrially-based communication services in the busier terminal areas: (1) the high volume of short distance communications is likely to be cost-effectively provided by terrestrial systems, (2) a strong signal path in both directions could be assured even for maneuvering aircraft, thus aiding operational efficiency by helping to guarantee instantaneous communication access, and (3) voice communications would be enhanced by the elimination of the delay periods characteristic of satellite communications.

Until satellite-based services for communications (and to support automatic dependent surveillance) become cost-efficient in such regions, high frequency (HF) communications will be used for en route operations in the high latitude and polar areas of the world.

3. REQUIRED LEVEL OF SERVICES

As stated earlier, the future system, by design, will have the capability to provide CNS services in essentially all airspace, from the surface to at least 70,000 feet for conventional aircraft and current supersonic transports. The system must also cater to later supersonic and hypersonic aircraft which may be required to provide information to ATC from up to near-orbital altitudes. However, the need for CNS services will be different for various areas of the world and operating altitude regimes, because of widely different traffic densities.

### 3.1 Services in High Latitude and Polar Areas

These areas of the world, outside the coverage of geostationary satellites, have low traffic densities and few airports. Navigation services will be provided by the global satellite navigation system, or by other suitable navigation capability. HF communications services, or a reduced capability satellite data link service provided by navigation satellites, if justified, could meet the communication needs for these areas. The surveillance function is likely to be satisfied in these areas by automatic dependent surveillance using available communications media. In terminal areas, terrestrial voice and data link services, including an automatic dependent surveillance service if needed, or even cooperative independent surveillance services, can be provided as the traffic levels and/or service needs justify such services.

### 3.2 Services in Other Low Traffic Density Areas

In addition to the high latitude and polar areas, there are other world areas where the traffic densities are expected to remain relatively low. These include oceanic areas and certain land areas. It is postulated that CNS services will be provided in a manner similar to those described for the high latitude areas, except for one major difference: geostationary communication satellite coverage will be available to provide voice and data link services both en route and in low traffic density terminal areas, and to provide the capability for automatic dependent surveillance, or satellite-based cooperative independent surveillance service where its need might be justified. Relatively simple earth stations, requiring little technical support, are likely to become available for location at airports or ATC centers where ground communications and other facilities are difficult to achieve. Where they can be justified, terrestrial voice and data link communication services, including automatic dependent surveillance service and, where appropriate, cooperative independent surveillance services can be implemented.

### 3.3 Services in High Traffic Density Areas

There are several areas of the world where traffic densities are high in much of the en route airspace as well as in terminal areas.

In addition to the basic level of CNS services described above, large areas of the en route airspace are anticipated to need cooperative independent surveillance (in addition to automatic dependent surveillance), and many terminal areas will use terrestrial cooperative independent surveillance (in addition to automatic dependent surveillance), extended at major airports to provide high accuracy surface and surveillance guidance from the same conceptual system. Terrestrial voice and data communications will also be used in these terminal areas.

## 4. SYSTEM FAILURE PROTECTION AND AVIONICS COMPLEMENT SIMPLIFICATION

The requirements for failure protection will remain high in the new CNS system; however, such failure protection can be achieved in the system described while permitting simplifications in the existing avionics complements.

A key in considering transition to a new system of communications, navigation, and surveillance, and in the acceptability of a transition to users, is the prospect of simplification of the avionics complement. In the concept described, two different kinds of equipage levels must be considered. For both the guiding ground rule is that no single element failure may deprive the system simultaneously of both navigation and surveillance. The assumption is that if navigation is lost, surveillance and communication must be available to the ground facility which can, in turn, communicate navigation guidance to the cockpit. Conversely, if surveillance and/or communication is lost, the aircraft must have the ability to continue to follow the flight plan previously agreed using its own navigation resources.

Examples

a. In environments where the air traffic control surveillance function is provided by automatic dependent surveillance only (i.e., no cooperative independent surveillance function is provided, either by satellites or terrestrially), and the integrity of the ground/space elements of navigation/communication services is very high, the minimum airborne complement could be two navigation units and one L-band communications transceiver/processor for voice and data communication. Two navigation units would be required since the failure of the navigation unit in a single-unit complement would cause the loss of both navigation and surveillance.

b. For environments in which cooperative independent surveillance is provided, the minimum airborne complement could be one navigation unit, one surveillance unit, and one L-band communications transceiver/processor for voice and data communications. The surveillance element might be integrated into the communications transceiver/processor as another modem card. In this case, the simplified avionics system might be comprised of two units--the navigation unit and the surveillance/communication unit. (For the case of the synchronized ranging cooperative independent surveillance option, barometic altimetry information could be a part of the interrogation response, possibly crosschecked by vertical information from the satellite navigation system.)

c. A common positioning determining system supporting both navigation and surveillance needs may become practical. Such a system would integrate separate sources of information and provide a single output of aircraft position to be used for both ATC and navigation purposes. Such a concept would need to be designed in such a way that complete loss of source data can never occur.

For both a and b, above, it is assumed that the communication functions for both satellite relay and terrestrial based communication services can be accommodated in one airborne transceiver. It is also assumed for b, above, that the cooperative independent surveillance functions for both the satellite-based and terrestrial services can be integrated into the same unit. Efficient avionics packaging would be significantly simplified if the transmission/modulation formats of the satellite-based and terrestrial services for each of the functions are identical or compatible.

Not included in this listing are other systems, such as inertial navigation systems, which are likely to remain a valuable part of large transport navigation systems, or HF communications, which may be needed for high latitude/polar flights. The Microwave Landing System is not listed, but would be required if precision approach and landing operations are needed.

Collision avoidance systems are also not included. If the cooperative independent surveillance system of the future is a functional evolution of Mode S, the data source and communications functions would remain available for the collision avoidance services. If other means of cooperative independent surveillance evolve, a collision avoidance system would need either to be fully independent or would need to use the position (and possibly time information) provided by the evolved navigation system.

The functional and conceptual evolution of the Mode S system, resulting in the future terrestrial cooperative independent surveillance system, is likely to include trilateration modes which can serve not only for surveillance in a terminal area, but may also be able to provide the accuracy and precision required for on-airport surveillance, navigation guidance, and control.

## 5. CONSIDERATION OF THE IMPLEMENTATION OF NEW CNS SYSTEM ELEMENTS

Historically, long lead times have been required for the introduction of new aeronautical radio services. It must be possible to introduce the new CNS system and its elements in a practical, cost-effective, and evolutionary manner. This is important since the initial number of users may be small, and thus the user base for some interim period may not readily justify the capital and operational costs of a system supported by a large user population.

### 5.1 Navigation System Implementation

The implementation of the postulated global coverage satellite navigation system presents, at least in the early years before 2010, the smallest problem (relative to other CNS system elements). This is due in large part to initiatives already being pursued aimed at establishing a worldwide navigation capability for many applications.

If the presently planned satellite navigation system(s) cannot provide the needed performance capability and integrity to support "sole-means" aeronautical navigation service, decisions will need to be made regarding how a "sole-means" service can be achieved. This could include: (1) additional monitoring stations worldwide, and (2) a decision to add satellites to the nongeosynchronous constellation(s), or a decision to extend capability on a regional basis by adding space segment capability at appropriately located geostationary positions (e.g., navigation packages on communication satellites of opportunity).

### 5.2 Communication System Implementation

It is probable that satellite services for air-ground communications will be provided to serve certain areas of the world by geostationary satellites (except for high latitude/polar areas). Such services can be capacity

tailored and controlled on a regional basis to meet the needs of the separate world regions. A number of potential suppliers will provide services as the number of users grows. To insure the most cost-efficient service possible, only service capacity adequate to meet then-current needs would be procured. In later years, when a large user base is established, economics might justify satellite services dedicated to aeronautical communications (e.g., transponders or satellites).

A satellite-based minimum data link capability provided to high latitude/polar areas by special transponders on navigation satellites can serve as a replacement for HF when such service can be justified.

The implementation of satellite system-compatible terrestrial communications systems is anticipated to evolve by area, based on the number of users. Prior to full implementation and transition, the satellite-based service could be used, where available, possibly with a higher increment of power for terminal area users, as an addition to the then-present terrestrial communications services, or as a new service if no satisfactory service exists.

### 5.3 Surveillance System Implementation

Automatic dependent surveillance services initially will be provided by use of satellite-based, terrestrial, and HF communication systems as appropriate.

As discussed previously, there are two principal means of providing satellite-based cooperative independent surveillance. The major drawback of the three-dimensional surveillance concept described above (2.2a) is that, although functionally capable, it may be costly to implement and maintain (especially considering the space segment costs). This high cost is due primarily to the need for satellites in special orbits, which might dictate that these satellites would have to be dedicated to aeronautical system use only.

The two-dimensional synchronized ranging concept (2.2b) is potentially more cost-effective to implement, especially in the early years when the user base is not large. This concept could be realized using suitably spaced geostationary communication satellites and with only the capacity needed to serve the then-current user base. Automatic dependent surveillance is anticipated to be adequate for the high latitude/polar areas and equatorial areas where this concept cannot be applied.

## 6. SYSTEM TRANSITION CONSIDERATIONS

The issue of transition will remain important and perhaps controlling. It is likely that satellite services will be based heavily on commercial services and commercial satellites which may be beneficially shared with other services--if the stringent requirements for aviation safety services can be met. The aviation system will, as before, remain as flexible as possible to permit the most economic and efficient choices to be made, particularly in the use of communications services. The key need is to achieve early worldwide standardization of basic satellite communication parameters to assure interoperability.

The inevitable question of when current systems will be withdrawn will, of course, face the aviation community. The timing of withdrawal of currently existing systems will depend on many factors, and the transition will, of necessity, be slow. Decisions to withdraw currently existing systems will be based on the implementation and quality of the new systems, the perceived need for retention by various elements of the aviation community, the willingness of governments and users to continue financing eventually redundant systems, and a variety of other factors.

Mr. BROWN. You're probably going through your budgetary process for fiscal year 1988 at the present time, or it's under way. We're not talking about a large number of dollars, you've indicated that yourself, we're talking about a few million possibly in these R&D program elements. If I'm the chairman, and I think any chairman of this subcommittee is going to want to look next year at your budget very carefully to see that there is proper emphasis given to these areas in the light of this exploratory session.

It's my personal intent to use this hearing as a basis for further and more extensive exploration of this because of my interest both in the NAS plan and better utilization of our satellite programs that are coming along, including GPS and the advanced communication technology satellites and so forth. I want to see these programs integrated in a way that the public gets the maximum benefit out of these. I think you probably share that view.

Mr. PORTIZKY. Yes, sir.

Mr. BROWN. But you are under a different set of constraints than we are, and we may have different priorities because of that.

I don't know whether you can provide us with a full answer to this question now, but we would like to have you give us an estimate of the evolutionary timing that the basic NAS plan can or will be followed by satellite enhancements. I may not have phrased that properly, but I think you get the thrust of what I'm talking about.

We expect the satellite capabilities to be coming on line, and we expect the NAS plan to be cognizant and to accommodate that. I want to see if you can give us a little estimate on timing as to these things.

Mr. PORTIZKY. Well, sir, that's a dangerous game, of course.

Mr. BROWN. Yes, and don't endanger yourself too much. You can always amplify in writing.

Mr. PORTIZKY. Let me comment very briefly.

I believe that there is reason to expect that, probably before 1990, we will begin to see satellite communications services over the oceans. They may not be provided by FAA. We hope, indeed, they will be provided by commercial providers.

We want, as I've indicated, within the system structure on which we hope to get international agreement, to have enough quality in that communication link to use it for air traffic control. In a way, that's the ideal way to do it. My belief is that we will see such services probably before 1990 or certainly in the very early 1990's.

I should think that automatic dependent surveillance capability will follow in very short order. The Airlines Electronic Engineering Committee is now at work with us and with the ICAO fans group to agree on how we mechanize it—what are the messages, what the process is. That will be the oceanic application, perhaps first in the Pacific, perhaps in the Caribbean, perhaps in the Atlantic.

I would think the next most attractive service will turn out to be, my crystal ball says, in underdeveloped parts of the world. It will become perfectly apparent that aircraft can prospectively save major amounts of fuel in the useful application of satellite communications and automatic dependent surveillance over the oceans—that's a moneymaker, I believe. In underdeveloped areas there is the potential for providing a service which just simply won't get

there any other way, in my view, so my take is that the next step will be that sort of implementation.

I believe we will begin to see, and until the late 1990's in domestic environments, the beginning applications of space technology, beyond the leased satellite point-to-point services which are already there and don't require special investment. The process will be slow; it will be driven—because it is in most cases not a safety requirement but an efficiency requirement, by the industry itself. We, the Government, can provide better services, with satellite capability, but a wise man once said that a requirement is a need that we're willing to pay to solve. So I think it's a community endeavor.

Mr. BROWN. Well, we appreciate that estimate.

Now you have already indicated that you feel that all of this can be accommodated within the NAS plan, that the NAS plan is the building block on which we can construct these enhancements as we go along without too much difficulty. Are you sure of that?

Mr. PORTIZKY. Well, let me try to say it directly, and then perhaps Lee would want to amplify.

If you believe, as we believe, that satellite services are not air traffic control, but are tools the air traffic control system can use, then the major NAS Plan investment that's being made must be made.

Is there an adaptation required when a service goes from a radar to a satellite surveillance scheme? Of course there's adaptation needed. There are technical gadgets that are required to take the new information, or information that comes in a different form, and that will of course add costs.

There's one more point I'll make quickly. On the data link activity, Mr. Palmer mentioned the mode S data link and talked about incompatibility between that and the satellite links. We are well aware of the need for what has come to be called open system interconnection, I won't trouble you to define it, but it means that you create the data streams, the messages for the mode S data link, for the satellite data link, for the airline operational control data link, all in such a way that the systems can interoperate with each other with a minimal modification of either the ground facilities—there will be some—or the avionics facilities.

In sum, of course there will be need for changes, there will be adaptations, there will no doubt be improvements, but the mainstream work we are doing is the foundation for what has to follow.

Lee, would you want to comment on that?

Mr. BROWN. Well, I may be wrong, but it's my anticipation that we will see a more rapid development in some of these satellite and space-based technology applications, an accelerated progress in this area, and I don't want to see us fail to recognize and accommodate to that should I be correct. I'm not always correct, but once in a while I hit it lucky.

With regard to the space segment that we're talking about here, we're talking about the need for new or different or better communications satellite facilities both in geostationary orbit and possibly in some orbits—in polar orbits in some locations. At present, the commercial industry is providing most of these facilities, and we would assume that would continue. Is that correct?

Mr. PORITZKY. Yes, we would hope so, Mr. Chairman, in the communications area. In the navigation area, of course, the premier system is GPS.

Mr. BROWN. I was going to get to that.

Mr. PORITZKY. I'm sorry. In the communications area, I think that's true.

Mr. BROWN. Yes. Of course what we have thought was necessary was the continued role of the Federal Government, through NASA or whatever, in helping to bring along these advanced technologies which may be the pacing factor in some of these things. I won't even ask you if you agree with that.

But getting to the GPS, this is a Government-owned and operated system. Does your thinking contemplate the possibility of a commercial space segment that would fulfill the same sort of need, or are we thinking here of utilizing this in-place system or its enhancements—and it will be continually enhanced—by a commercial sector which would use the facility but would translate it into commercial utilization on a far broader basis than at present?

Mr. PORITZKY. Well, Mr. Chairman, I'm not sure I can give you anything but a personal answer on that, and I'll give it on that basis. I noted in the full version of my testimony that the United States has a very large investment in GPS; it counts in the billions.

Mr. BROWN. I know.

Mr. PORITZKY. To my way of thinking, it would be damn foolishness not to use that to its full extent. I believe it will be used by truckers and——

Mr. BROWN. Is there any reason why it shouldn't be used? Does it compromise national security, or does it do anything else that would be disadvantageous?

Mr. PORITZKY. I believe not, Mr. Chairman. The President said he would make it available worldwide. I think a number of people are counting on it.

As I mentioned, there are competing systems. In the Soviet GLONASS there are satellites up; the Europeans with NAVSAT have hopes of having a service available. Much of the cost of GPS is sunk, it's already there, and more of it will be. We believe it has the potential, not exactly in its present form but as it will evolve, to provide sole means of navigation. I think it is likely to be by far the least expensive way to go with satellite navigation.

Mr. BROWN. Isn't it also true that overall cost effectiveness for a global system would be enhanced through a degree of cooperation between the other parties that you have mentioned so that we have a more comprehensive system that's integrated to all—so that all users can take advantage of it? Is that a possibility?

Mr. PORITZKY. Yes, sir, we think it's a possibility. One of the problems is that while the United States has made available a great deal of information on GPS, predominantly after KAL-007 and even before, the other major prospective provider, the Soviet Union, has told us almost nothing.

In the ICAO FANS group—there is a significant amount of movement. A number of people say, "Wait a minute; if these systems are virtually identical, as they appear to be, and if there are 18 plus 3 GPS satellites and 8, 12—pick a number—GLONASS satellites, wouldn't it make sense?"

We are at this moment exploring the view the United States should take when this matter is discussed at the FANS meeting which will come up in November. My own view is that there is no issue of technology transfer. The world knows pretty well what GPS is. We can't do very much about exploring the other aspects until some information is released on GLONASS.

Mr. BROWN. Well, I don't know how to explain that problem. It may be just the mutual paranoia that exists between our two countries, but we have overcome that in connection with the SARSAT system, for example.

Mr. PORITZKY. Yes, sir.

Mr. BROWN. And there's no real reason why we shouldn't overcome it with these other systems as far as you and I can see at the present. At least you haven't indicated any.

Mr. PORITZKY. That's my personal view, sir, yes.

Mr. BROWN. But you don't control the State Department or anything like that.

Mr. PORITZKY. That's true.

Mr. BROWN. That's a true statement. Neither do I.

Mr. PORITZKY. They're helping us in developing a proper viewpoint for us to take.

Mr. BROWN. All right. Thank you very much, Mr. Poritzky.

Let me just say in conclusion, I have indicated rather casually that this is an exploratory hearing. I think I should state rather firmly that we intend to continue with a more indepth exploration of this in the spring, and I would request now that you take the necessary steps to explore some of the issues and points made in the testimony of both the GAO and other parties, because we will be using that as a basis for further exploration with you.

Mr. PORITZKY. Yes, sir.

Mr. BROWN. I'm not saying that in a critical way at all but merely so that you will be alert to this possibility, say, in February or March of next year.

Mr. PORITZKY. Yes, sir.

Mr. BROWN. Thank you very much, both of you, you and Mr. Page.

Mr. PORITZKY. Thank you.

Mr. BROWN. The subcommittee will be adjourned.

[Whereupon, at 12:35 p.m., the subcommittee was adjourned.]

[Additional material submitted for the record follows:]

ARINC AERONAUTICAL RADIO, INC.
2551 RIVA ROAD • ANNAPOLIS, MARYLAND 21401 • 301-266-4000

September 25, 1986

The Honorable George E. Brown, Jr.
Chairman
Subcommittee on Transportation, Aviation,
and Materials
Rayburn House Office Building
Room 2321
Washington, D.C. 20515-6306

Dear Mr. Chairman:

I appreciate the opportunity to provide this statement on the application of satellite technology to air traffic control systems. I would like to share with you our views on several topics related to aviation communication, i.e., the air transport industry's aviation satellite program (AvSat), satellite radio spectrum concerns and needs and, lastly, general observations concerning air transport industry institutional arrangements for communications.

ARINC is the communications company of the air transport industry. It was organized by the civil aviation community in 1929, at the suggestion of the Federal Radio Commission, to ensure efficient utilization of the scarce aeronautical radio spectrum and to coordinate aeronautical telecommunications generally. ARINC is owned by members of the airline industry, including large and small air carriers, general and corporate aviation. ARINC has been an active participant in RTCA SC 155 and IACO FANS activities.

ARINC currently provides the aviation community with air-ground voice and data communications over domestic and international air routes on a not-for-profit basis. Through ARINC's stewardship of the aeronautical spectrum, the ever increasing needs of aviation have been efficiently accomodated over 55 years of growth. During the past half century, essential facilities have been made available to existing air carriers, new entrants, and general aviation. ARINC directly, and through its committees such as the Aeronautical Frequency Committee and the Airline Electronic Engineering Committee, has been active in future communications planning for the aviation industry.

A SUBSIDIARY OF ARINC INCORPORATED
FIFTY-FIVE YEARS OF SERVICE TO THE AIRLINE INDUSTRY

## 1. Background

Aviation has been dependent upon air-ground communications for safe, efficient flight operations from its earliest days. Indeed, it would not be an exaggeration to state that aeronautical communications are as important to aviation as the central nervous system is to the human body. Thus, consistent with domestic and international requirements, air-ground communications now provide the means to satisfy industry needs for air traffic control and other air traffic services, exchange of weather information, aircraft operational control, airline administrative message transmission, and even passenger telephone service.

The need for these services is rapidly increasing and is outstripping available communications capacity, particularly for air traffic control and aircraft operational control. FAA administrator Donald Engen recently noted that "our skies are crowded and air traffic volume is increasing at nearly double-digit rates." Saturation of existing communications channels has made it more difficult to serve new aircraft operators and queueing delays in heavy traffic areas have increased. Because of the high speeds at which aircraft travel, such delays inevitably increase safety risks.

Historically, the aviation industry accommodated its expanding communications needs through technological innovation bringing greater efficiency in spectrum use. Unfortunately, advances in state-of-the-art equipment alone are no longer adequate to meet the burgeoning demand. For example, the FAA has had to impose "high density" rules restricting traffic flow in five major airports in an attempt to reduce air traffic control delays. Nonetheless, such delays continue to grow at an alarming rate and may require the extension of restrictions to other airports.

Not only is the current system marginal, and potentially inadequate, to meet existing and projected demand, its technological performance is in many respects inadequate. Airlines now primarily utilize VHF AM radio operating at frequencies near the FM broadcast band for voice and data services, but this system is limited to line-of-sight transmission. Thus, aircraft operating beyond land masses must use separate HF radios operating in a different frequency range. The performance of HF radio, however, is dependent upon ionospheric conditions, is subject to fading and interference, and often provides only poor quality communications. Moreover, voice services, which remain the principal type of ATC air-ground communications available today, are poorly suited to support advanced and safety-enhancing communications capabilities such as automatic digital data transmission for operational control communications.

In contrast, innovations in satellite design and digital communications techniques now promise major advances in both the

number and quality of services available to the air transport industry. Satellites have obvious application to aviation, due to their ability to "see" large regions of flight traffic. Such a capability could offer dramatic improvements in aviation safety and efficiency in both domestic and oceanic regions. Although the present NAS plan does not include use of satellites, this technology will soon be available for use by aviation, whether or not it is used for ATC. Accordingly, the FAA and this committee should encourage the evolution of the NAS plan into a system which can use these aviation satellite facilities.

## 2. Aeronautical Spectrum Requirements

The potential of an aeronautical satellite system has been discussed for several years. The International Telecommunication Union has allocated spectrum at L-Band, 1545-1559 MHz and 1646.5-1660.5 MHz, for a global aeronautical mobile satellite system dedicated to the safety and regularity of flight. These allocations were ratified by the Senate as recently as December 1982 and implemented by the FCC later that year.

The FCC recently reiterated the importance of this AMSS allocation. Although the FCC in rulemaking Docket 84-1234 chose to permit sharing of 18 MHz of the AMSS L-Band spectrum with new land mobile satellite services--an action inconsistent with the international allocation and concerning which ARINC has strong reservations--the agency has stated that communications necessary for the safety and regularity of flight would continue to have priority over other services in the band.

Notwithstanding this apparent affirmation of the need for an aeronautical satellite system, ARINC remains concerned about the safety implications of the FCC's decision. Recent studies by ARINC and other members of the air transport industry indicate that the full L-Band allocation will be required to meet aeronautical needs; further we firmly believe that co-primary sharing between an aeronautical mobile satellite service and other consumer services is unwise and would jeopardize aviation safety. The industry will continue its efforts to persuade the FCC to reconsider its decision, and suggests this Committee may want to review the dangers inherent in this situation, as well as the potential for international friction that it will create.

## 3. The AvSat System

As a result of increasing service requirements and the advent of new technologies and delivery systems, civil aviation has been evaluating the operational utility of an aeronautical satellite system for some time. In the past eighteen months, efforts have accelerated and the interest of the aviation community is best demonstrated by the large

and supportive attendance at a first-ever aviation satellite conference held September 16-18 at ARINC in Annapolis, Maryland--representatives of 35 domestic and foreign air carriers, most foreign and domestic avionics firms, Boeing, McDonnell Douglas, FCC, FAA, and State Department attended.

In July 1985, the ARINC Board of Directors adopted a resolution endorsing establishment, through ARINC, of an industry-owned integrated aeronautical satellite system which can provide air traffic control, aircraft operational control, aeronautical administrative, and passenger telephone services. As ARINC itself is owned by the air transport community, the industry-operated AvSat system will be responsive to user needs yet consistent with domestic and international regulatory obligations. For example, ARINC currently provides over-ocean aviation communications for both company operational control and air traffic control, the latter to assist the FAA in meeting the agency's governmental responsibilities. The Future Air Navigation Systems panel of the International Civil Aviation Organization also has recognized the potential for such an industry-owned system.

In response to its Board's directive, ARINC has developed a design for an aviation industry satellite system (AvSat) that will meet user demand, promote aviation safety and efficiency, and provide new flight deck and cabin services. In contrast to the alternative of control by governments or communication common carriers, the AvSat initiative provides the best hope for a global system that offers safety-of-flight priorities and cost-based charges.

The AvSat design concept is an integrated digital satellite communications and surveillance/navigation system utilizing the most modern avionics and satellite technologies. In developing the AvSat design, a critical consideration was the need to provide not only for a system which could meet worldwide demand into the distant future, but for orderly implementation of that design on an initial limited basis.

The key requirements which the AvSat system design addresses include:

- Serves all aviation--air transport, business, and general aviation
- Integrated system providing safety service (ATC and AOC) voice and data, cabin voice and data, and independent and dependent surveillance
- Compatibility to accommodate worldwide variations in traffic demand
- Global service under common international standards

- o Accommodation of future technological advances, especially those that bear on spectrum conservation

- o Interchangeability of voice and data channels providing efficient use of available radio spectrum.

Initially, the AvSat program expects to provide service utilizing "add-on" packages (transponders) on multiple payload satellites. This system is intended to meet near term aviation needs in 1988 to increase the reliability of over-ocean voice communications in the Pacific and Atlantic and to extend existing ARINC enroute data services to over-ocean areas. Appropriate transponders will be leased from the satellite owners for the required period.

The system ultimately will be expanded to six geosynchronous satellites spaced sixty degrees apart providing global coverage. ARINC, on behalf of the world's aviation community, has requested the Federal Communications Commission to "Advance Publish" with the International Frequency Board (IFRB) its intent to utilize the AMSS frequency allocation at the appropriate orbital positions in order to ensure that the AvSat system has proper orbit allocations.

Terrestrial interconnection with the space segment to relay aircraft communications will be provided through industry owned-and-operated ground stations. The system design has been carefully chosen to permit service access to space segment by small low-cost communications earth terminals to reflect the economic and political needs of countries and administrations throughout the world. It is currently planned that the first industry/ARINC earth stations will be located on the East and West coasts of the United States and Hawaii. These locations will provide reliable redundant facilities in view of the initial three satellite locations.

It should be noted that the system design is currently being coordinated as an international avionics standard by the Airlines Electronic Engineering Committee (AEEC). AEEC has been the primary vehicle for avionic standardization in the international air transport industry for more than 40 years; ARINC provides the supporting secretariat and engineering for this very large international activity. Industry and government administrations throughout the world have looked to AEEC to ensure form, fit, and function interchangeability of avionics, thereby assuring competitive sources of avionics on an international basis. In this regard, ARINC expects to foster competitive procurements for space segment, avionics, and earth stations in acquiring its system components. To illustrate the scope of AEEC activities, a comprehensive index of its specifications is attached.

4. AvSat Services

The AvSat system will use the internationally allocated L-Band frequencies to meet requirements for transport, business, and general aviation aircraft. The avionics and functional capabilities involved will be fully integrated to include comprehensive communications support for the needs of aviation including:

- o Air traffic control
- o Aircraft operational control
- o Administrative communications
- o Surveillance and navigation
- o Passenger telephone service

AvSat will provide aviation authorities--including the Federal Aviation Administration, if desired--with reliable means of sending and receiving air traffic control (ATC) data and voice information for enroute aircraft. ARINC expects ATC increasingly to rely upon data for routine transmissions, especially for "transport" aircraft operated by the major airlines. AvSat will provide an integrated capability for communications covering approach and ground control, automatic terminal information service messages, departure and enroute control, position surveillance reporting, enroute clearance and meteorological reports. Today, many of these services are provided by a combination of systems requiring multiple sets of radio equipment on board each aircraft.

Aircraft operational control (AOC) provides communications for flight regularity--the safe, expeditious and economical operation of aircraft and the protection of life and property while the aircraft is in service. AvSat will accommodate AOC communications through digital data and voice messages. For example, AvSat will offer virtually continuous real time monitoring of the flight and safety status of critical aircraft components, allowing the diagnosis of mechanical difficulties before failure. It also will provide expanded data message transfer capability for scheduling, routing, passenger and cargo manifests, fuel consumption, and seating occupancy.

AvSat's surveillance function will provide aircraft position information to assist ground control of aircraft. Surveillance information will be derived from the AvSat ranging system integral to the communications links necessary for AvSat's own control operations. Alternatively, AvSat could provide a relay for positions determined aboard the aircraft or from other positioning sources.

Aeronautical administrative communications carried by AvSat involve information exchange between the aircraft and the operating agency for more routine actions on aircraft service and operations.

Finally, AvSat will provide a new worldwide, high quality, continuous passenger telephone service for business or personal use.

Critical to the AvSat prioritization system is the fact that all services, whether safety or nonsafety, are integrated under common control. This unique system design ensures that top priority safety messages--such as mayday calls--will always be transmitted instantaneously. Lower priority messages may utilize the same spectrum only during non-emergency periods, and only subject to termination if necessary for the transmission of safety messages.

AvSat is designed to provide all of these services in an efficient and technologically advanced manner with a very high standard of performance. When fully developed, AvSat will have ample capacity to ensure that safety traffic can always get through and that blockage of other transmissions will be minimal. Unlike present aviation communications, AvSat will be able to combine multiple services in a single set of avionics, thus more easily accommodating power, space, weight and air drag limitations on aircraft.

## 5. Institutional Observations

The United States air transport industry recognized many years ago that services provided by government agencies and communications common carriers throughout the world have been conspicuously lacking in responsiveness and cost efficiency; deregulation in the early 1980's has served to emphasize these views. Even U.S. Federal agencies are not immune from criticism as evidenced by recent proposals of the air transport industry and ATA to restructure the Federal Aviation Administration into a federal corporation.

In the United States, ARINC has historically provided to aviation oceanic air traffic control communications, airline operational control communications, switched data network services to interconnect the industry's data systems, microwave transmission facilities, and other communications and database utilities. ARINC is proud of the efficiency with which its operations are conducted; as an example it may be noted that ARINC switches and delivers a message between any two air carriers for less than one cent per message.

ARINC and the air transport industry were the first to deploy an operational air/ground data link, ACARS, for use by air transport and business aviation. This network first came into being in 1977 and today its use is growing at an annual rate of 70% per year and currently is delivering more than 2.5 million messages a month between more than 2,000 equipped aircraft and airline operations; ACARS has been adopted as an airline international standard and is now being deployed in Asia and Europe.

These specific examples of ARINC services provided to the air transport industry on a not-for-profit basis are cited to demonstrate the responsiveness and effectiveness of an industry-owned private sector communication facility. It is interesting to note that ARINC's ACARS air-ground data-link and its switched data network could today support substantial automation of ATC functions and thereby improve the cost and operating efficiency of air transport operations. The FAA has not elected to explore or utilize these existing operational facilities.

In keeping with the industry's historical institutional preference, in March 1985 ARINC's Board of Directors adopted a resolution calling for ARINC to foster an international industry owned and operated satellite system for use by aviation, constructed in accordance with international standards established by the AEEC. The AvSat program is a direct outgrowth of this resolution.

The obverse of the resolution is that the industry does not believe that communications common carriers, whether Post and Telegraph organizations, Intelsat, INMARSAT, or similar organizations will be suitably responsive to its needs. In this connection, there are several questions concerning the statutory authority of Comsat and INMARSAT to offer aeronautical services which will ultimately be brought to the attention of Congress.

6. Conclusion

Mr. Chairman, the aviation community strongly supports an aviation satellite system. It recognizes that the vital safety and regularity of flight communications required by aviation can be met only by a space-based, global, compatible, and dedicated system. It is our belief that the AvSat system will bring the benefits of modern satellite technology to the pilot, the controller, and the traveller--it is the best choice for the future of aviation communications.

Yours truly,

George F. Mansur
President
Chairman of the Board